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FOREWORD

The project Sustainable Boreal Forest Resources has as an overall objective to generate quantitative contributions to a sustainable development concept for the boreal forest zone with respect to forest utilization, environmental and socioeconomic aspects.

This project is also carrying out forest activities together with the IIASA project Environmentally Compatible Energy Strategies. The objective of this cooperation is to analyze how the forest sector can help to mitigate the emissions of greenhouse gases. This report is a result of the cooperation between the two projects within IIASA and deals with the potential of forest biomass for energy production in mainly Europe and has been produced by the IIASA scholar Wolfgang Schopfhauser.

ABSTRACT

In this analysis, the forest biomass utilization and the potential for energy production for Western and Eastern Europe, Russia and China has been estimated. Western and Eastern Europe are assessed on a country level and Russia and China as regions. Current trends and developments of forest resources characterize their ability to produce forest biomass for energy production. Europe is characterized by a slowly increasing forest land area, underutilization of the forest resource, and increased growing forest stock and an estimated increase in wood energy production by 25-75 % by year 2020. Limitations of the Russian forest resource are due to a major share which is actually not exploitable and because natural hazards and overexploitation in populated areas threaten the growing stock. Nonetheless, by far the largest biomass resource of the studied regions is located in Siberia. China has faced heavy overutilization of its forests without appropriate reforestation and protection. Despite a decline of forest area and forest productivity, the harvesting has increased. This situation is expected to continue, which may even increase pressure on forest exploitation. Forest biomass potentials are compared with total biomass potentials by IIASA's ECS-Project. The possibility of a forest plantation program to contribute to the enhanced production of forest biomass for energy production is analyzed.

Key words: Forest biomass, fuelwood, renewable energy, potential, Europe, Russia and China

THE CURRENT AND POTENTIAL PRODUCTION OF FOREST BIOMASS FOR ENERGY IN EUROPE, RUSSIA AND CHINA

Wolfgang Schopfhauser

1. INTRODUCTION

As energy is closely related to significant environmental impacts, a more sustainable production of energy is assumed to be a crucial factor in the management of global change problems. In the short to medium term sustainable energy production is primarily feasible by using renewable energy sources, such as solar radiation, wind and tidal stream resources, geothermal energy pools and biomass. Except for geothermics, solar radiation is directly or indirectly involved in the availability of renewable energy sources.

Solar radiation averages 1000 W/m^2 for 1200 hours per year resulting in some 12000 MWh/ha/a. From which thermal solar collectors, driven either with air or water, can produce 3000 MWh/ha/a and photo voltaic applications 1000 MWh/ha/a. In contrast, plants have one of the lowest energy input/output ratios regarding stored energy of approximately 1% of solar radiation. Depending on the biomass production, strategies such as wood from forests, straw and grass can produce 13-16 MWh/ha/a and short rotation forestry[1] 45-90 MWh/ha/a (Plank, 1994).

Current or foreseeable amounts of available forest biomass for energy are linked to forest management. Therefore the potential of forest biomass can be referred to as total forest biomass that is available as *growing forest stock,* that is either available through *actual* or *allowable felling operations* on an annual basis and that is foreseen to be used as *source for energy production,* which refers to the actual amount of available bioenergy. Potentials that are derived from growing stocks serve as an indicator on how much biomass is totally available,

[1]Data for temperate zone biomass production.

which is of primary interest for long-term planning and policy making. In contrast, quantities derived from felling operations give a picture on the availability of biomass quantities on an annual basis which is more closely related to the development of markets and technology. The bioenergy potential is the share of biomass that is derived from the previously described potentials which is dedicated to energy production.

Bioenergy potentials have high uncertainties regarding the future available quantities. The uncertainties are caused by the competing utilization of timber and the energy prices on the world energy markets. In the forest industry highest increases in wood consumption are foreseen in the pulp and paper and particle board industry, both using biomass which is highly competing with bioenergy production (UN, 1996). Consequently, forecasts on the utilization of timber are quite complex and are not subject of this assessment. Furthermore, no analyses have been carried out with respect to advancements of energy technologies and changed economic conditions for bioenergy.

Definition of biomass

The term biomass energy refers to all fuels that are derived from plants, notably wood and residues originating from agriculture and forestry (deGroot, 1989). According to full product cycles in the forest sector, biomass as plant matter is not only apparent in final products but also in a variety of by- and waste products such as wood residues and bark, pulping liquors, waste wood, demolition wood, non-forest biomass, and waste paper.

In forestry, primary interest has been paid to stemwood at the exploitation of forest biomass. The interest in increasing wood and fiber yields have led to total plant biomass predictions. There are different definitions available for biomass, particularly for forest biomass. Cost *et al.* (1990) gives a definition of *forest biomass*, that is the weight of all living woody plants above the ground, and of *tree biomass* which refers to wood and bark in all living trees, which corresponds to merchantable stemwood. According to other definitions, total tree biomass may include the entire tree components and aboveground tree biomass components above a 15 cm stump (Alban *et al.* 1978). In general, forest biomass includes either all or only aboveground (with or without stump) tree components and not only merchantable masses. Nonetheless, different definitions of biomass and inconsistent units in statistics and estimations create problems in assessing a European wide biomass energy potential.

Potential

Due to the objectives of the analysis carried out, different potentials can be distinguished, e.g. theoretical, technical, economical and real potential. Regarding biomass energy utilization the *theoretical* potential depicts the highest values which can be described as the maximum determined limits but which do not provide any information on the actual availability of biomass. In contrast, the *technical* potential takes into account the limitations in biomass exploitation, by the utilization and logistics. The technical potential is the most commonly used potential in the literature (Rakos, 1993; Kaltschmitt and Wiese, 1994)

The *economical* potential uses real prices of biomass production, its utilization and market penetration as a starting point; its weak point is uncertain forecasts of future price developments of other energy carriers and of biomass utilization for competing uses. An *ecological* potential may take into account environmental limitations. Finally, the *real* potential is the final step in a potential assessment including additional assessments on investments and socioeconomics. Due to its complexity and interdisciplinary approach and considerable amount of detailed information the real potential is difficult to estimate.

Tendency in biomass use

Currently, fossil fuels dominate the world energy consumption (84% in 1992; CEC, 1993). Hall (1991) estimates the share that biomass has of the total energy production to be 14 % or 55,000 PJ. Wood and charcoal contributes by 18,000-21,000 PJ and most of it in the form of traditional biomass such as fuelwood (Hall, 1991; WEC, 1992). While production figures for roundwood and traditional fuelwood have increased steadily by 1.4 %, respectively 1.7 % per year at a global level during 1982-1993, in Europe roundwood production increased slightly by 0.1 % and fuelwood consumption declined by 0.5 % per year (FAO 1995). Forest biomass for energy production and product substitution, remains subject to dependence on fossil fuel prices, limitations on alternative energy sources and their market penetration, allocation of research and development budgets, and interests for the established primary energy carriers.

This hinders non-stemwood biomass to be used for new purposes, such as replacement for energy-intensive materials and to compete with fossil fuels on the global market as well as to substitute them.

Regarding the economics of renewable energy sources, Keel (1994a) distinguishes between business economics and political economics. While costs in terms of business accounting are currently higher for biomass energy production compared to energy generation based on oil, the opposite is true in terms of political economics; a more dynamic impact on the regional economy as well as a higher "regional surplus value" may be achieved by a biomass fueled strategy (Keel, 1994a).

Furthermore biomass has a huge potential for substituting energy-intensive materials such as aluminum, steel and plastics and for improving its energy and carbon input/output balance. Wood for example is well suited as building and construction material but experiences small quantitative proportions for such long-living products. In addition to fossil fuel substitution, material replacement has the greatest potential for carbon dioxide reduction (Sikkema and Nabuurs, 1994).

Biomass exploitation

With regard to biomass, the aim of the exploitation of a truly renewable energy sources is restricted by sustainable management regimes. During the past century a understanding of sustainability in European forestry has been established defining the annual allowable cut of timber to be less than the annual biological regrowth or increment. This approach is based on timber harvests but seems to be much more complicated to establish for total plant biomass extraction.

Assessment of biomass energy use and its resource

By estimating the current biomass energy use and biomass potential, decisions on resource allocation and its utilization can be made. Scurlock and Hall (1990) argue that there have been carried out "very few independent and comprehensive reviews of biomass energy useage". The same is true for assessments of biomass potentials. Therefore information has been collected from national and regional sources in a synoptic way in order to derive to a up-to-date state of the art in this field. According to Scurlock and Hall (1990) this "approach obviously leads to a greater estimate of the contribution of biomass as a whole to energy supply than is given by official statistics".

As documented in this study, a national bottom-up approach for estimating the wood energy consumption results in a higher quantity of roundwood used for energy purposes than indicated by FAO (1995), UN (1994c) and other sources. The UN (1996) addresses indirectly this problem by stating that more than 45 % of the volume of annual wood removals in Europe is used for energy. When assessing the share of roundwood that is finally turned into energy in each wood consuming sector, a direct link to roundwood consumption can be established.

Most official statistics, like FAO (1995) and UN (1994c), account for fuelwood and industrial roundwood referred to as roundwood. It can be assumed that most wood for energy production that is documented, is directly related to commercial roundwood such as fuelwood, industrial by-products or waste fiber. This is why limited information is available on what kind of wood fiber fractions beside industrial roundwood are used for energy production and to which extent. Seldom, the fraction of forest biomass energy excluding roundwood is accounted for.

As mentioned earlier, the problem of inconsistencies in data and units arise specifically at assessments of biomass utilization for energy production. On one hand there is only poor statistical documentation available, and on the other hand heating values are either not defined in these statistics or differ from each other. Table 1.1. provides an overview of estimates on the gross energy content of forest biomass.

Table 1.1. Overview on selected references on the gross energy content of forest biomass.

Source	Fuelwood	Biomass waste[1]	Reused wood[2]
Austropapier, 1995[3]	-	7.4 GJ/t	7.4 GJ/t
Engert, 1982	14.6-15.6 GJ/t (15-20%)[4]	-	-
Hall *et al.*, 1994	15.0 GJ/t (20%)[4]	-	-
Hakkila, 1989	14.8-15.8 GJ/t (20%)[4]	-	-
Kaltschmitt & Wiese, 1993	14.7-15.5 GJ/t (15%)[4]	-	-
Rakos, 1993	12.0 GJ/t (25%)[4]	11.0 GJ/t	13.0 GJ/t
Smil, 1994	16.0-23.0 GJ/t (15-50%)[4] Charcoal 28.0-30.0 GJ/t	-	-
Winkler-Rieder, 1993	15.5 GJ/t	9.2 GJ/t	-
Sikkema, 1993	16 GJ/t (10-15%)[4]		

[1] Includes bark, pulping liquors and sawing industry by-products.
[2] Reused wood includes waste wood and demolition wood.
[3] Calculated end-use energy content.
[4] Refers to moisture content in %.

The energy content of biomass is determined by the help of the content of carbon which is fairly stable but with a slightly higher extent in conifers (51 %) than in deciduous trees (49 %) (Engert, 1993; Kaltschmitt and Wiese, 1993). The energy content is given by Kollmann in Hakkila (1989) to 17.4-18.2 GJ/t in cellulose, 25.5 GJ/t in lignin, and 35.6-38.1 GJ/t in resins. The effective heating value is, besides small variations in the chemical composition of biomass, mostly dependent on the moisture content. Each percentage of increased moisture decreases the heating value by 0.2 GJ/t of wood (Kaltschmitt and Wiese, 1993). An average heating value, at 15-20 % moisture in wood, corresponds to 14-15 GJ/t (Hakkila, 1989).

National assessments of the current and potential use of biomass energy do not clearly separate biomass energy carriers and bioenergy producers, user or consumers. In addition to the national surveys and estimations, a series of publications provide homogenized data, which can be applied to most countries. Although most of these use different definitions a plausible estimation is possible particularly if these data are calibrated by national statistics and estimations.

There are two statistics available, FAO's fuelwood statistic (1994) and UN's statistics on fuelwood (1994a), which offer volume and mass based information on fuelwood and charcoal respectively. Both sources do not provide any information on bioenergy users. Regarding UN's statistics on fuelwood (1994a) data are taken from information provided by the Food and Agricultural Organization (FAO) with the exception of a series of Asian and African countries as well as Luxembourg and Sweden. The conversion of fuelwood volume to weight is based on a factor of 0.625 t/m^3 for coniferous wood and 0.750 t/m^3 for non-coniferous wood (FAO, 1994). These conversion factors correspond to an estimation by the UN (1994a), which accounts for 9.67 GJ/m^3 on average. NUTEK (1993) suggests 8.5 GJ/m^3 for coniferous wood and 10.1 GJ/m^3 for deciduous wood for timber removals in Europe. For charcoal a conversion factor of 0.167 t/m^3, according to FAO (1994), has been employed. The energy content of charcoal has been assumed to be 28 GJ/t (Smil, 1994). Data on national import and export balances are taken from UN (1994a) and converted according to FAO (1994) by 0.725 t/m^3 and 14 GJ/t.

The European Commission's Statistical Office (EC, 1994b) has published renewable energy source statistics for 1989, 1990 and 1991, which aggregate primary energy production of biomass and wastes. It splits the commodity wood, wood waste and other solid waste besides municipal solid waste and biogas into producers and consumers for households, industry, district heating and power stations. Although "the use of biomass and waste is predominately in the form of firewood consumption" an overestimation of the actual woodfuel consumption may occur due to the use of straw and other agricultural solid waste for energy production.

Hall *et al.* (1994) have published a comprehensive, country by country, estimate of biomass energy consumption for 1987, which is based on various sources. They state that only FAO publishes a country by country estimate of fuelwood and charcoal production. Some of the data used in that study refer to information provided by FAO. NUTEK (1993) has presented an aggregated overview of the forest fuel potential dealing with fuelwood production, forest industry residues subtracted by other uses of forest industry residues, and the unused forest fuel potential (the total annual forest increment subtracted by total removals). IEA (1995) has documented unpublished data on the annual available energy potential from forestry and timber industry residues which are presented country by country. In this study information on the number of inhabitants and national primary energy consumption is taken from EC (1994a) and refers to the year 1992. Percentages of the area of forests and woodlands of total national areas are subtracted from FAO (1993).

2. RESOURCES AND POTENTIALS

2.1. CURRENT STATE OF EUROPEAN FORESTS

Forest resources in Western and Eastern Europe are characterized by underutilization, increased growing stocks and a slowly increasing forest land area. This trend is expected to continue due to economic, social and political considerations.

The use of wood for energy production experiences a diverting situation. In rural areas traditional wood-based bioenergy use declines due to a wider availability of more convenient and more user-friendly energy sources such as natural gas. In contrast the installed capacity of "new" renewables has risen rapidly (Grubb, 1995). Modern bioenergy production technology, such as small-scale low-emission wood chip burning equipment and decentralized wood-fueled heating plants with district heating grids, steadily gain ground. CEC (1991) concludes that increased use of forest residues in industry is likely to be offset by declining use in the domestic sector over the next two decades.

Although forests have been surveyed for centuries, the information is still not consistent. The area of Europe's forests and woodlands (165 million ha) is made up by 130-133 million ha of exploitable closed forests and by 31-34 million ha of non-exploitable forests (23-25 %) which corresponds to 34 % of the total land area. The growing forest stock is estimated to be 18.4 to 19.2 billion m^3 in 1990. There is a growing unused timber resource (81-233 million m^3) due to a substantially higher net annual increment (566-632 million m^3) removal (343-399 million m^3). Forest biomass which is lost or left on site in the forests account to 33-62 million m^3. Overall descriptions of the national forest resources are given in Table 2.1.

Table 2.1. Key data on exploitable forest resources in Europe.

Country	Land area [mill. ha]	Forests & woodlands [mill. ha]	Exploitable closed forests [mill. ha]				Growing stock of stemwood [mill. m³ o.b.]			
Reference year	1991	1991	1981	1987	1990	1990	1981	1987	1990	1990
Source	FAO (1993)	FAO (1993)	UN (1986)	Nilsson (1992a)[1]	UN (1992)	Pajuoja (1996)	UN (1986)	Nilsson (1992a)[1]	UN (1992)	Pajuoja (1996)
Finland	30.5	23.2	19.4	19.3	19.5	19.5	1568.0	1662.8	1679.0	1790.1
Norway	30.7	8.3	6.6	5.2	6.6	6.6	575.0	430.3	571.0	630.0
Sweden	41.2	28.0	22.2	23.4	22.0	22.0	2264.0	2359.9	2471.0	2556.8
NORDIC	**102.3**	**59.5**	**48.3**	**47.9**	**48.2**	**48.1**	**4407.0**	**4452.9**	**4721.0**	**4976.9**
Austria	8.3	3.2	3.2	2.8	3.3	3.3	797.0	775.7	953.0	967.0
Switzerland	4.0	1.1	0.8	1.1	1.1	1.2	312.0	397.5	360.0	365.0
CENTRAL	**12.3**	**4.3**	**4.0**	**3.9**	**4.4**	**4.5**	**1109.0**	**1173.2**	**1313.0**	**1332.0**
Belgium + Lux.[5]	3.3	0.7	0.7	0.6	0.7	0.7	86.0	94.9	110.0	110.0
Denmark	4.2	0.5	0.4	0.4	0.5	0.4	46.0	61.2	54.0	55.1
France	55.0	14.6	13.3	13.2	12.5	13.5	1550.0	1587.7	1742.0	1800.5
Germany	34.9	10.4	9.4	9.8	9.9	10.2	1502.0	2142.4	2674.0	2809.4
Ireland	6.9	0.4	0.3	0.3	0.4	0.3	32.0	27.6	30.0	31.3
Italy	29.4	6.8	3.9	4.8	4.4	4.4	557.0	737.2	743.0	744.0
Netherlands	3.4	0.3	0.3	0.2	0.3	0.3	23.0	22.8	52.0	50.2
U.K.	24.2	2.4	2.0	1.9	2.2	2.3	203.0	207.8	203.0	246.9
EEC-9	**161.3**	**36.2**	**30.4**	**31.3**	**30.8**	**32.1**	**3999.0**	**4881.6**	**5608.0**	**5847.4**
Albania	2.7	1.5	0.9	0.9[7]	0.9[7]	0.9	80.0	79.0[7]	79.0[7]	71.7
Greece	12.9	2.6	1.8	1.9	2.3	2.3	133.0	142.1	149.0	149.0
Portugal	9.2	3.0	2.6	1.5	2.3	2.3	189.0	132.8	167.0	149.5
Spain	49.9	15.9	6.5	5.6	6.5	6.4	453.0	381.1	450.0	462.9
Turkey	77.0	20.2	6.6	15.9	6.6	6.6	637	920.9	759	759
F.Yugoslavia[6]	25.5	9.1	8.5	8.0	7.8	7.7	1084.0	1107.9	1056.0	1063.4
SOUTHERN	**177.2**	**52.3**	**19.4**	**17.1**	**18.9**	**18.7**	**1859.0**	**1763.9**	**1822.0**	**1824.8**
EU	**313.2**	**112.1**	**86.1**	**85.9**	**86.8**	**87.9**	**9403.0**	**10336.0**	**11477.0**	**11922.7**
Bulgaria	11.1	3.9	3.3	3.2	3.2	3.2	298.0	338.8	298.0	405.0
Czech Rep.	10.3	2.6	2.5[9]	2.4[9]	2.6[8]	2.6	589.1[9]	549.5[9]	615.0[8]	617.0
Estonia[8]	4.3	1.9	1.9	1.9	1.9	1.9	240.0	240.0	240.0	240.0
Hungary	9.2	1.7	1.6	1.5	1.3	1.6	253.0	253.5	229.0	280.0
Latvia[8]	6.2	2.8	2.2	2.2	2.2	2.3	351.0	351.0	351.0	351.0
Lithuania[8]	6.3	2.0	1.7	1.7	1.7	1.6	280.1	280.1	280.1	288.4
Poland	30.4	8.8	8.4	8.4	8.4	8.4	1162.0	1293.9	1380.0	1385.2
Romania	23.0	6.7	5.9	6.2	5.4	5.4	1268.0	1104.8	1202.0	1202.0
Slovak Rep.	4.9	2.0	1.9[9]	1.8[9]	2.0[8]	2.0	333.9[9]	311.4[9]	348.5[8]	383.3
EASTERN	**108.4**	**33.9**	**30.3**	**30.2**	**29.6**	**29.9**	**4855.1**	**4802.0**	**5022.6**	**5223.6**
TOTAL	**481.9**	**164.5**	**132.4**	**130.4**	**131.9**	**133.3**	**16229.1**	**17073.6**	**18486.6**	**19204.7**

Table 2.1. continuing. Key data on exploitable forest resources in Europe.

Country	Annual stemwood increment [mill. m³ o.b.]				Annual stemwood removals [mill. m³ o.b.]					Unrecovered harvesting losses[11] [mill. m³ o.b.]		Unused stemwood resource[12] [mill. m³ o.b.]			
Reference year	1981	1987	1990	1990	1981	1987	1990	1990	1993	1981	1990	1981	1987	1990	1990
Source	UN (1986)	Nilsson (1992a)[1]	UN (1992)	Pajuoja (1996)	UN (1986)	Nilsson (1992a)[1]	UN (1992)	Pajuoja (1996)[13]	FAO (1995)[2]	UN (1986)	UN (1992)	UN (1986)	Nilsson (1992a)[1]	UN (1992)	Pajuoja (1996)
Finland	61.9	61.9	69.7	81.6	50.7	47.5	44.6	50.2	45.1	4.6	11.2	11.2	14.4	25.0	31.4
Norway	17.3	13.5	17.6	20.7	10.3	11.8	10.1	13.1	11.3	0.6	1.7	7.0	1.7	7.5	7.6
Sweden	66.9	70.1	91.0	91.3	52.8	61.4	48.0	60.3	72.5	4.4	9.6	14.1	8.7	43.0	31.0
NORDIC	**146.2**	**145.4**	**178.3**	**193.6**	**113.8**	**120.7**	**102.7**	**123.6**	**128.9**	**9.6**	**22.5**	**32.4**	**24.8**	**75.6**	**70.0**
Austria	19.6	17.6	22.0	30.4	14.5	16.9	15.0	17.9[14]	14.2[14]	0.6	2.3	5.1	0.6	7.0	12.5
Switzerland	5.2	6.1	5.8	5.9	4.3	5.4	4.5	6.7	5.1	0.2	0.8	0.9	0.7	1.3	0[17]
CENTRAL	**24.8**	**23.7**	**27.8**	**36.3**	**18.8**	**22.3**	**19.5**	**24.6**	**19.3**	**0.8**	**3.1**	**6.0**	**1.3**	**8.3**	**12.5**
Belgium + Lux.[5]	4.8	4.5	4.6	5.2	2.7	3.9	3.3	3.7	4.7	n.a.	0.4	2.1	0.5	1.3	1.5
Denmark	3.4	3.3	3.5	4.2	1.9	2.4	1.8	2.0	2.4	n.a.	0.5	1.5	0.9	1.7	2.2
France	54.0	52.9	65.9	67.9	37.6	47.4	43.2	50.4	51.2	3.8	4.8	16.4	5.5	22.7	17.5
Germany	53.5	56.9	59.2[3a]	83.8	43.7	49.6	42.7	57.6[15]	43.4[15]	3.2[4]	3.2[4]	9.8	7.3	16.5	26.2
Ireland	2.5	2.0	2.0[3b]	3.5	0.7	1.5	1.4	1.5	2.2	0.0	0.2	1.8	0.4	0.6	2.0
Italy	11.9	14.8	14.8[3b]	13.6	7.7	9.6	7.3	7.6	10.4	0.4	0.4	4.2	5.3	7.5	6.0
Netherlands	1.2	0.9	2.4	2.3	1.1	1.4	1.1	1.3	1.5	0.1	0.2	0.1	-0.5	1.3	1.0
U.K.	11.2	10.8	8.5	12.2	4.3	5.9	6.4	5.9	7.1	0.3	1.7	6.9	4.8	2.1	6.3
EEC-9	**142.6**	**146.2**	**160.8**	**192.7**	**99.7**	**121.8**	**107.1**	**130.0**	**122.9**	**7.8**	**11.4**	**42.9**	**24.4**	**53.7**	**62.7**
Albania	2.9	1.2[7]	1.2[7]	1.3	1.6	2.0[7]	2.0[7]	2.1[16]	2.7[16]	0.0	0.1[7]	1.3	-0.8	-0.8	-0.8
Greece	3.7	3.5	3.3	3.3	0.7	3.4	2.5	2.9	3.3	0.0	0.9	3.0	0.1	0.8	0.4
Portugal	11.4	6.5	11.3	11.3	8.5	11.5	7.8	9.9	14.2	n.a.	3.1	2.9	-5.0	3.5	1.4
Spain	27.8	24.1	27.8	29.0	13.2	21.9	12.1	15.1	18.5	0.1	2.9	14.6	2.2	15.6	13.9
Turkey	19.2	25.6	19.8[18]	19.8	19.3	17.8	12.2	12.2	16.9	0.3	4.5	-0.1	7.8	7.6	7.6
F.Yugoslavia[6]	27.8	28.1	27.7	28.5	15.3	17.4	15.0	14.7	14.0[19]	4.7	4.7	12.5	10.7	12.7	13.8
SOUTHERN	**70.7**	**62.2**	**70.0**	**72.1**	**37.7**	**54.3**	**37.4**	**42.6**	**69.6**	**4.8**	**11.6**	**33.0**	**7.9**	**32.6**	**29.5**
EU	**334.0**	**329.8**	**385.8**	**439.6**	**240.1**	**284.5**	**237.1**	**286.3**	**290.6**	**17.5**	**38.2**	**93.9**	**45.4**	**148.8**	**153.3**
Bulgaria	6.0	5.8	5.8	10.6	4.9	5.1	3.5	3.7	4.1	1.1	1.2	1.1	0.7	2.3	6.9
Czech Rep.	11.1[9]	14.8[9]	18.8[8]	18.9	15.1[9]	14.5[9]	12.0[8]	13.3	11.4	3.5[9]	1.3[8]	-4.0	0.3	6.8	5.6
Estonia[8]	8.4	8.4	8.4	8.4	3.0	3.0	3.0	3.1[16]	2.5[16]	0.3	0.3	5.4	5.4	5.4	5.3
Hungary	9.6	9.2	8.2	9.7	6.5	7.1	4.8	6.0	5.0	1.1	1.2	3.1	2.1	3.4	3.7
Latvia[8]	7.0	7.0	7.0	7.0	5.0[10]	5.0[10]	5.0[10]	5.2[16]	4.8[16]	1.2	1.2	2.0	2.0	2.0	1.8
Lithuania[8]	7.6	7.6	7.6	7.7	3.3	3.3	3.3	2.8[16]	3.6[16]	0.4	0.4	4.3	4.3	4.3	4.9
Poland	28.5	27.0	30.5	30.4	24.2	27.3	22.1	21.4	22.0	1.1	5.2	4.3	-0.3	8.4	9.0
Romania	26.9	34.1	31.6	31.6	19.5	26.9	14.2	15.5	15.5	0.2	1.7	7.4	7.2	17.4	16.1
Slovak Rep.	5.7	7.6	9.7[8]	11.4	6.4[9]	6.2[9]	5.1[8]	5.2	5.7	1.5[9]	0.5[8]	-0.7	1.4	4.6	6.2
EASTERN	**113.7**	**122.7**	**128.8**	**137.0**	**89.5**	**100.4**	**75.0**	**78.3**	**74.6**	**10.4**	**13.1**	**24.2**	**22.3**	**53.8**	**58.7**
TOTAL	**498.0**	**500.2**	**565.7**	**631.7**	**359.5**	**419.5**	**341.7**	**399.1**	**415.2**	**33.4**	**61.7**	**138.5**	**80.7**	**224.0**	**233.4**

[1] Refers to Nilsson *et al.* (1992a).
[2] Figures are given in solid volume of roundwood without bark (m^3 u.b.); they have been converted by factors for bark from Nilsson et al. (1992a) to m^3 o.b.
[3a] Figure constitute data from Nilsson *et al.* (1992a) for Fed. Rep. of Germany and from UN (1992) for Dem. Rep. of Germany.
[3b] Figure taken from Nilsson *et al.* (1992a).
[4] Figure taken from UN (1992) and refers to Fed. Rep. of Germany only. Luxembourg included in Belgium.
[5] Luxembourg included in Belgium.
[6] Figures refers to former Yugoslavia.
[7] Figure taken from UN (1994e).
[8] Figures taken from UN (1994d).
[9] Figures are derived by splitting numbers for Former Czechoslovakia according to proportional forest resources for the two new republics as given in UN (1994d).
[10] Figure refers to total forest area.
[11] Figures are derived by subtracting figures for annual stemwood fellings from annual stemwood removals.
[12] Figures are derived by subtracting figures for annual stemwood removals from annual stemwood increments.
[13] Pajuoja's data (1995) are given in m^3 u.b.; they have been converted by factors for bark from Nilsson et al. (1992a) to m^3 o.b.
[14] Conversion factor for bark from Nilsson et al. (1992a) is corrected to 1.15.
[15] Conversion factor for bark from Nilsson et al. (1992a) is corrected to 1.2.
[16] Conversion factor for bark from Nilsson et al. (1992a) is corrected to 1.05.
[17] According to Pajuoja (1995) there would be overcutting in the order of -0.8 million m^3 in Switzerland which is assumed to be incorrect.
[18] Number not available and therefore Pajuoja's information (1995) employed.
[19] Figure refers to year 1990.

2.2. NATIONAL RESOURCES AND POTENTIALS IN EUROPE

2.3.1. FINLAND

Current use of biomass for energy

Finland's forest cover rate of 76 % of the total land area or 23.2 million ha is one of the highest in Europe. With a population of 5.1 million, a huge forest resource contrasts a rather small range of potential bioenergy users. Despite this limitation the value of domestic energy resources, hydropower and bioenergy seems to be recognized widely, which is expressed in a share of bioenergy use in the range of 15-17 % of total energy consumption (1223 PJ) (Sipilä *et al.,* 1992; FMTI, 1993). Finland's current bioenergy production is based on wood derived fuels (13-15 %) and peat. The cited references present mostly aggregated numbers with limited information on different biomass commodities.

The Finnish forest industry plays a vital role in the national use of wood-based fuels. Verkasalo (1992) estimates the domestic energy use by the Finnish forest industry to be 135 PJ in the period of 1991-1992 of which 122 PJ is provided by wood-based fuels and 18 PJ by peat. Rämö (1994) presents the same number for the forest industry and 175 PJ for the total

Finnish wood-based fuel requirements in 1993. Two sources, the Finnish Ministry of Trade and Industry (FMTI,1993) and Alakangas (1994), present 156 PJ respectively 155 PJ of wood-fuel use in 1992. Sipilä *et al.* (1992) estimate this number to be 188 PJ. Data published by EC (1994a) for biomass energy use in Finland amount to 192.6 PJ primary energy production. FMTI (1994) estimates a consumption of 210 PJ of indigenous fuels in 1993, others than peat (62 PJ) and hydro power.

According to Rämö (1994) the non-industrial wood-fuel requirements amounted to 40 PJ in 1992 and according to the Finnish Ministry of Trade and Industry (FMTI, 1993) to 34 PJ. The Finnish Forest Research Institute's statistics (FFRI, 1994) split this number into fuelwood consumption (29 PJ) and wood residues (5 PJ) in 1993. FAO (1994) describes the fuelwood production to be 29 PJ for the same year while Hall *et al.* (1994) give the use of the same commodity to 32 PJ. In Hakkila (1985) the use of small-tree and logging residue amounts to 3 PJ in 1982.

Table 2.1. Current use of wood derived biomass for energy production in Finland in PJ[1].

Ref. year / Source / Activity	1993 FFRI (1994)	1993 FMTI (1994)	1992 FMTI (1993)	1992 Alakangas (1994)	1993 Nilsson (1995)	- Sipilä *et al.* (1992)	1991 Verkasalo (1992)	1992 EC (1994a)	1987 Hall *et al.* (1994)[6]	1992 FAO (1994)
Forest industry	-	-	-	-	26.3	-	122	-	-	-
Pulping liquors	-	-	87.5	-	136.4	96.3	-	-	-	-
Fuelwood	29.2[3]	-	34.2	-	42.5	-	-	-	32	29.4[8]
Residues	5.4[4]	-	-	-	-	-	-	-	-	-
Indust. waste	-	-	34.2[5]	-	29.2[10]	-	-	-	-	-
Total use of woodfuels	-	209.6[9]	155.8	154.9	234.4	188.4	-	192.6[2]	150[7]	-
Peat	-	61.8	57.7	58.6	-	41.9	-	-	-	-

1 If not otherwise indicated, original numbers derived according to the conversion of 1 toe = 41.868 GJ.
2 Refers to biomass for primary energy production.
3 Volume based number (4.64 million m^3) converted by 0.45 t/m^3 and 14 GJ/t.
4 Volume based number (0.97 million m^3) converted by 0.4 t/m^3 and 14 GJ/t.
5 Includes industrial waste wood and municipal refuse.
6 Original numbers given in PJ.
7 According to Biomass User Network; includes all forms of biomass consumption for energy in various years in the 1980's.
8 Refers to the description in Chapter 1.
9 Refers to other indigenous fuels.
10 Refers to district heating.

Potential use of biomass for energy

NUTEK's biofuel forecast (1993) presents a potential of 466 PJ which is primarily provided by 341 PJ of unused annual forest increment. Hakkila (1985) listed the technical potential of small-tree and logging residue reserves to be 85 PJ. According to Sipilä et al. (1992), the potential of additional use of forest residues depends on the employed harvesting method, which is the explanation for a wide range in the estimation of future potentials (75-138 PJ). Alakangas (1994) estimates the potential increase in biomass energy to be 56 PJ.

Asplund (1994) estimates the not systematically harvested forest biomass (forest residues etc.) to be about 45 mill. m^3/year (252 PJ; converted according Table 2.2., footnote 4). Furthermore, he states, that if all raw material for chemical pulp production would be processed by means of an integrated production of pulp chips and fuel fraction, the amount of wood for energy production could be raised by up to 10 mill. m^3/year or 56 PJ. IEA (1995) presents a potential of 360 PJ which consists of forest (289 PJ) and industrial residues (71 PJ). A limited potential is foreseen by energy crops by Alakangas (1994).

Table 2.2. Potential use of wood derived biomass for energy production in Finland in PJ[1].

Source / Activity	Asplund (1994)[1]	Hakkila (1985)	Sipilä *et al.* (1992)	Solantausta *et al.* (1994)[3]	Alakangas (1994)[4]	IEA (1995)	NUTEK (1993)
Add. harvesting	-	85.2[1]	75.4-138.2[2]	-	56.0[1]	-	341
Fuelwood	-	-	-	-	-	-	29
Forest residues	-	-	-	-	-	289.0	-
Industrial residues	-	-	-	-	-	71.0[6]	96
Additional residues	56-252	-	-	-	-	-	-
Technical potential	-	-	263.8-326.6	213.5-339.1	355.9[5]	360.0	466

[1] Volume based numbers converted by 0.4 t /m^3 and 14 GJ/t.
[2] Range depends on future harvesting technique.
[3] Potential additional sources given by this reference are added to the current use of 4.1 Mtoe or 171.7 PJ.
[4] Weight based numbers converted by 41.868 GJ per Toe.
[5] Includes all forms of bioenergy and refers to the year 2010.
[6] The given potential is already partially used.

2.2.2. *NORWAY*

Current use of biomass for energy

Norway's forest area accounts to 8.3 million ha or 27 % of the land area. Currently 2-6.5 % of the Norwegian primary energy consumption (892 PJ) is provided by forest biomass energy. Norway has a population of 4.3 million and a fuelwood production of 10-17 PJ (FAO, 1994; Hall *et al.*, 1994; NUTEK, 1993; Norsk Bioenergiforening, 1990).

A significant share of the current woodfuel production is contributed by the forest industry (Lunnan and Moen, 1991; Norsk Bioenergiforening, 1990; Norsk Bioenergiforum, 1993; Sollesnes, 1994). The total wood based energy production has been estimated to vary from 21 to 37 PJ during recent years (see Table 5).

Table 2.3. Current use of wood derived biomass for energy production in Norway in PJ.

Ref. year Source Activity	- Gislerud (1994)[2]	1990 Lunnan and Moen (1991)[2]	- Norsk Bioenergi-forening (1990)[2]	1991 Norsk Bioenergi-forum (1993)[2,4]	1993 TFB (1994)	1992 Hall *et al.* (1994)	1990 Sollesnes (1994)	1992 FAO (1994)
Fuelwood	-	6.7	16.6	-	-	10.0	18.0	10.1[1]
Forest residues	-	0.7	-	-	-	-	-	-
Bark	-	-	-	2.6	2.8	-	-	-
Industry residues	-	8.3	18.7	4.3	-	-	11.5	-
Pulping liquors	-	-	-	10.3	8.1	-	7.9	-
District heating	-	-	-	3.4[3]	-	-	-	-
Total use	36.0	15.7	36.0	20.6	10.9	32.0[5]	37.4	-

[1] Refers to the description in Chapter 1.
[2] Original number converted from TWh to PJ by factor 3.6.
[3] Includes residual wastes and wood-based fuels.
[4] Refers to forest biomass energy production in the forest industry only.
[5] According to Biomass User Network; includes all forms of biomass consumption for energy in various years in the 1980's.

Potential use of biomass for energy

Lunnan and Moen (1991) present detailed cost-related potentials of biomass based energy carriers which add up to 63.7 PJ in the year 2000. In contrast, the Norsk Bioenergiforening (1990) and Gislerud (1994) describe that up to 108 PJ could be derived from bioenergy production at the same year. While Lunnan and Moen's technical potential is supported by IEA (1995), NUTEK (1993) supports the number of Gislerud.

Table 2.4. Potential use of wood derived biomass for energy production in Norway in PJ.

Source / Activity	Lunnan and Moen (1991)[1]	Norsk Bioenergi-forening (1990)[1]	Paaske (1982)			Gislerud (1994)[1]	IEA (1995)	NUTEK (1994)
Ref. year	2000	-	1990	2000	2020	-	-	
Add. harvesting	15.6	-	-	-	-	-	-	86.0
Thinnings	1.2	-	-	-	-	-	-	-
Forest residues	5.9	-	-	-	-	-	54.0	-
Fuel wood	13.3	-	-	-	-	-	-	10.0
Industry residues	22.0	30.2	-	-	-	-	13.0[2]	12.0
Energy plantations	5.7	-	-	-	-	-	-	-
Technical potential	63.7	108.0[3]	27	61	87	108.0[3]	67.0	108.0

1 Original number converted from TWh to PJ by factor 3.6.
2 The given potential is already partially used.
3 Refers to total biomass production

2.2.3. SWEDEN

Current use of biomass for energy

Sweden has one of the highest percentages (68 %) of forest area (28.0 million ha) of the land area in Europe. The forest resource was used at an early stage for energy production. A population of 8.7 million covers some 13 % of its primary energy consumption (1955 PJ) by biofuels (including peat).

The forest industry, particularly the pulp and paper industry contributes with 95-166 PJ to the 1991 forest biofuel use for energy purposes of 226 PJ (Skogsindustrierna, 1993; NBF, 1994). Libäck (1994) and Hillring (1994) have estimated the woodfuel consumption to amount to some 216 PJ in 1992 with 101 PJ, respectively 132 PJ contributed by the pulp and paper industry. Furthermore, heating contributes by some 49 PJ in 1990 (NBF, 1994). The Swedish Statistical Office SCB (1994) lists 256 PJ of primary wood energy in 1992. FAO (1994), Hall *et al.* (1994) and UN (1994a) suggest a fuelwood production of 44, 47 respectively 122 PJ.

Table 2.5. Current use of wood derived biomass for energy production in Sweden in PJ.

Activity / Ref. year / Source	1992 Libäck (1994)[1]	1992 Hillring (1994)[1]	1991 Sogsindustrierna (1993)	1992 NBF (1994)[1] All uses	1992 NBF (1994)[1] Heating	1992 SCB (1994)	1987 Hall *et al.* (1994)	1992 UN (1994)
Sawmill residues	23.4	25.2[2]	8.1[4]	25.6	-	-	-	-
Pulp/board industry	100.8	131.8[3]	63.3[5]	132.1	4.7	-	-	-
Black liquors	-	-	-	-	-	-	-	-
Industrial residues	-	-	-	-	-	-	-	-
Fuel wood	-	39.6	23.3[6]	-	-	-	47	122.2[7]
Bark	28.8	-	-	-	-	-	-	-
Industrial electricity	-	-	-	8.6	-	-	-	-
District heating	19.8	19.8	-	20.2	-	-	-	-
Power stations	-	-	-	-	9.0	-	-	-
Residential use	43.2	-	-	39.6	35.3	-	-	-
Total use	216.0	216.4	94.7	226.1	49.0	255.6	230[8]	-

1 Original numbers in TWh, converted by a factor of 3.6 to PJ.
2 Refers to utilization of biofuels in other industry, principally saw-mills.
3 Refers to pulp and paper industry only.
4 8 % of 23 million m^3 converted by 0.4 t/m^3 and 11 GJ/t after Rakos (1993).
5 23 % of 25 million m^3 converted by 0.4 t /m^3 and 11 GJ/t after Rakos (1993).
6 8 % of 52 million m^3 converted by 0.4 t /m^3 and 14 GJ/t.
7 Refers to the description in Chapter 1.
8 According to Biomass User Network; includes all forms of biomass consumption for energy in various years in the 1980's.

Potential use of biomass for energy

Lundström et al. (1993) calculated the annually available theoretical energy potential from forest biomass to be 640 PJ but current harvesting restrictions limit this amount to 161 PJ up to the year 1997. Due to increased increment rates this latter amount is estimated to be 221 PJ in the year 2007. Two similar assessments which have been undertaken by Lundström (1994) and SIND (1983) give the potentials of 206 PJ and 165 PJ respectively. IEA (1995) and NUTEK (1993) have presented higher biomass energy potentials, 436 and 595 PJ respectively. Marklund (1981) has described the total energy content of Swedish forests to be 12,050 PJ.

Table 2.6. Potential use of wood derived biomass for energy production in Sweden in PJ.

Activity / Source	Lundström *et al.* (1993)[1] 1997	Lundström *et al.* (1993)[1] 2007	SIND (1983)	IEA (1995)	NUTEK (1993)
Additional harvesting	-	-	-	-	400
Fuel wood	-	-	-	-	35
Industrial residues	-	-	-	88.0[2]	160
Forest residues			165.1[3]	348.0	
Tree branches	153.0	210.5	-	-	-
Tree tops	7.9	11.0	-	-	-
Technical potential	160.9	221.5	165.1	436.0	595

[1] Original numbers take current harvesting restrictions into account and are given in TWh; converted by a factor of 3.6 to PJ.
[2] The given potential is already partially used.
[3] Volume-based numbers (22.4 million m^3 conifers, 5.7 million m^3 non-conifers) converted with 0.4, respectively 0.5 t/m^3 and 14 GJ/t.

2.2.4. AUSTRIA

Current use of biomass for energy

In Austria, the area of exploitable forests amounts to 3.2 million ha, which corresponds to 39 % of the land area. Austria's share of wood energy use of the primary energy consumption (1,139 PJ) ranges according various sources between 6-13 % (Obernberger *et al.,* 1994; BMWF, 1994).

Thus, estimates on the current use of biomass as energy source differ widely. This inconsistency may be due to incomplete estimations. The highest available consumption is estimated to be 134 PJ by BMWF (1994), 120 PJ by Alder (1993), 110 PJ by Rakos (1993) and 105 PJ by BMwA (1993). These publications are assumed to overestimate the current biomass energy production due to unrealistic conversion factors for volume to weight (Obernberger *et al.,* 1994; Rakos, 1995). More accurate calculations give 66 PJ by Winkler-Rieder (1993), 72 PJ (Obernberger *et al.,* 1994), 63 PJ (data form Gerold, 1992 and Rakos, 1993) and 82 PJ (Schmidt and Hantsch-Linhart (1990). The EC (1994a) presents an estimate of 96 PJ for biomass in primary energy production in 1992.

Hall et al. (1994) present national data on fuelwood consumption to be 27 PJ and 100 PJ for all kinds of bioenergy uses, which includes wood, wood residues, and agricultural residues. The FAO (1994) statistics on fuelwood and charcoal production present an estimate of 26 PJ in 1992. The pulp and paper industry generated 40 % of its energy need from biomass, which corresponds to 23 PJ in 1993. These numbers are further broken down by biomass commodities in Table 2.7.

Table 2.7. Current use of wood derived biomass for energy production in Austria in PJ.

Ref. year Source Activity	1989 Alder (1993)	1988 BMWF (1994)	1991[1] Gerhold (1992) Rakos (1993)	1988 Winkler-Rieder, 1993	1987 Hall *et al.*, 1994	1987 Schmidt/Hantsch -Linhart, 1990	1994[2] Austropapier, 1995	1992 FAO, 1994
Fuelwood	90.2	92.0	31.9	55.3	27.0	57.2	-	26.4[7]
Chips[3]	8.0	10.0	8.8	5.3	-	4.7	-	-
Wastes[4]	15.0	21.3	**16.0**	5.7	-	15.7	20.0	-
Reused[5]	-	-	5.9	-	-	-	-	-
Bark	5.9	9.6	-	-	-	4.4	2.8	-
Others	0.9	-	-	-	-	-	-	-
Total use	120.0	132.9	62.6	66.3	100.0[6]	82.0	22.8	-

1 Volume based numbers from Gerhold (1992), heating values from Rakos (1993) and a conversion factor of 0.4 t/m^3.
2 Numbers for pulp and paper industry only.
3 Includes wood chips, sawmill industry by-products and forest residues.
4 Pulping liquors.
5 Reused wood includes waste wood and demolition wood.
6 Refers to all forms of biomass energy consumption in various years in the 1980's.
7 Refers to the description in Chapter 1.

Potential use of biomass for energy

A rather theoretical forest biomass energy potential has been calculated by NUTEK (1993). Thereby the unused forest fuel potential, the fuelwood production, and forest industry residues total 93 PJ. IEA (1995) estimates the annual available energy potential from forestry and timber industry residues to be 105 PJ.

Rakos (1993) provided scenarios for an increased use of biomass energy, distinguishing between moderate, engaged, enforced and maximal utilization. His data have later been adjusted by more accurate conversion factors for volume to weight and by this adjustment the biomass energy potentials for the foreseen scenarios are 68, 86, 97 and 101 PJ respectively. Winkler-Rieder (1993) estimates the potential to be 120 PJ in 2010. Schmidt and Hantsch-Linhart (1990) describe the potential to be 77-84 PJ. Obernberger (1995) describes the technical and economical feasible potential to be 50-65 PJ in 2005 out of a total theoretical potential of 130 PJ.

Table 2.8. Potential use of wood derived biomass for energy production in Austria in PJ.

Ref. year / Source / Activity	Rakos (1993)[1] Moderate	Engaged	Enforced	Maximal	2010 Winkler-R. (1993)	2005 Obernberger (1995)	Schmidt/ Hantsch-L. (1990)	IEA (1995)
Add. thinning[2]	3.7	7.3	7.3	7.3	2.7	-	-	-
Residues[3, 6]	10.6	10.6	10.6	10.6	12.9	-	-	80.0
Reused wood[4]	5.9	8.9	11.8	11.8	9.1	-	-	-
Fuel wood[2]	31.9	43.5	43.5	55.0	66.6	-	-	-
Short rotation forestry[2]	-	-	7.5	-	15.2	-	-	-
Less pulp and paper prod.[5, 6]	-	-	-	3.9	-	-	-	-
Ind. residues	-	-	-	-	-	-	-	25.0[9]
Wastes[7]	16.0	16.0	16.0	12.8[8]	13.5	-	-	-
Additional pot.	-	-	-	-	-	-		-
Tech. potential	68.1	86.3	96.7	101.4	120.0	50.0-65.0	80.0-95.0	105.0

1 Original numbers from Rakos (1993) have been corrected by an average conversion factor of 0.4 t /m³.
2 Energy content of 15 GJ/t from Rakos (1993).
3 Energy content of 11 GJ/t from Rakos (1993).
4 Energy content of 13 GJ/t from Rakos (1993).
5 Energy content of 13 GJ/t (average fuel wood and residue energy value) after Rakos (1993).
6 Enhanced waste paper recycling and waste avoidance is expected to decrease raw material demands in the pulp and paper industry by 20 %; subsequently this amount would become available for energy production.
7 Pulping liquors.
8 Wastes from pulp production have been reduced by 20 % due to[6].
9 The given potential is already partially used.

2.2.5. SWITZERLAND

Current use of biomass for energy

Switzerland's forest area adds up to 1.1 million ha which corresponds to 28 % of the land area. Currently the bioenergy production amounts to 1.5 % (Keel, 1994b) of the total primary energy consumption of 1059 PJ and 3 % of the heating consumption. With a population of 6.9 mill. Switzerland has a rather low wood-based energy consumption.

As displayed below 9 to 13 PJ of the primary energy production, is derived from wood or wood based fuels (BUWAL, 1990; Keel, 1994a; Planconsult, 1993; Schwank *et al.*, 1994). This corresponds to the estimate by Eicher *et al.* (1992) of 12.2 PJ. Similar wood-energy production totals and fuelwood production data by FAO (1994) and Hall *et al.* (1994) correspond with the Swiss references. The Swiss pulp and paper industry produced 2.1 respectively 1.9 PJ of bioenergy in 1992 and 1993 (ZPK/ASPI, 1994).

Table 2.9. Current use of wood derived biomass for energy production in Switzerland in PJ.

Ref. year / Source / Activity	1987 BUWAL (1990)	1993 Keel (1994a)	1991 Planconsult (1993)	1992 Schwank *et al.* (1994)	1992 Eicher (1992)	1992 FAO (1994)	1987 Hall *et al.* (1994)
Fuelwood	5.7[1]	8.3[1]	5.0[1,2]	-	-	8.5[3]	9.0
Waste wood	-	0.6[4]	3.8[4]	3.5[5]	-	-	-
Waste paper	-	-	-	7.0[6]	-	-	-
Residues	3.1[7]	-	4.5[7]	-	-	-	-
Chips	0.4[8]	2.9[7]	-	-	-	-	-
Total use	9.2	11.8	13.3	10.5	12.2[9]	-	-

[1] Volume based number converted by 0.45 t /m³ and 14 GJ/t.
[2] Includes fuelwood and charcoal.
[3] Refers to the description in Chapter 1.
[4] Volume based number converted by 0.4 t /m³ and an energy content of 13 GJ/t after Rakos (1993).
[5] Mass based numbers converted by 13 GJ/t after Rakos (1993).
[6] Energy content of waste paper 14.04 GJ/t (converted after BUWAL, 1992).
[7] Volume based number converted by 0.4 t /m³ and an energy content of 11 GJ/t after Rakos (1993).
[8] Volume based number converted by 0.4 t /m³ and an energy content of 11 GJ/t after Rakos (1993).
[9] 1 TWh converted to 3.6 PJ.

Potential use of biomass for energy

Switzerland has enforced an ambitious program, which is called *Energy 2000,* to stabilize the consumption of fossil fuels as well as CO_2 emissions by the year 2000 at or below the level of 1990 and to slow down the rate of increased electricity consumption. In addition to increased hydroelectric and nuclear power, renewable energy sources should contribute by 3 % to the heating energy and by 0.5 % to the electricity production (Schmid, 1994).

Eicher *et al.* (1992) estimate the short- and long-term potential of wood-based energy to be 22 PJ respectively 55 PJ, where the long-term potential is assumed to be the theoretical potential. In the same reference the potential for electricity generation from wood is expected to peak at 16 PJ in the long-term. According to Keel (1994a) the energy potential of wood ranges from 18 to 25 PJ depending on the harvesting intensity. The estimates by Schwank et al. (1994) correspond with the lower range of Keel's assessments. While NUTEK (1993) estimates a potential of some 49 PJ, IEA's potential (1995) suggests 38 PJ.

Table 2.10. Potential use of wood derived biomass for energy production in Switzerland in PJ.

Source / Activity	Eicher *et al.* (1992) medium	long-term	Keel (1994a)[1]	Schwank *et al.* (1994)	IEA (1995)	NUTEK (1993)
Additional harvesting	-	-	-	-	-	40
Waste paper	-	-	-	9.1[3]	-	-
Forest residues	-	-	4.8[4]	-	29.0	-
Waste wood	-	-	3.6[5]	8.6[2]	-	-
Fuel wood	-	-	8.4-15.7[6]	-	-	7
Non-forest wood	-	-	1.3[4]	-	-	-
Industrial residues	-	-	-	-	8.0[7]	2
Technical potential	22.0[8]	55.4[8]	18.1-25.4	17.7	37.0	49

1 Data for short to medium term availability.
2 Mass based numbers converted by 13 GJ/t after Rakos (1993).
3 Mass based numbers converted by 14 GJ/t (after BUWAL, 1992).
4 Volume based number converted by 0.4 t /m^3 and 11 GJ/t after Rakos (1993).
5 Volume based number converted by 0.4 t /m^3 and 13 GJ/t after Rakos (1993).
6 Volume based number converted by 0.4 t /m^3 and 14 GJ/t.
7 The given potential is already partially used.
8 1 TWh converted to 3.6 PJ.

2.2.6. BELGIUM and LUXEMBOURG

Current use of biomass for energy

These densely populated countries (10.0 million inhabitants) have a rather small forest area of 0.7 million ha (21 %). In 1992 the total energy consumption was 2117 PJ, of which some 0.7 % was contributed by wood energy.

Schenkel (1995) estimates some 13 PJ of wood as an energy source while EC (1994b) estimates 14 PJ. Fuelwood consumption, which only accounts partly for the total wood energy consumption, is estimated to 5-6 PJ (FAO, 1994; Hall et al., 1994; UN, 1994a).

Table 2.11. Current use of wood derived biomass for energy production in Belgium and Luxembourg in PJ.

Reference year / Source / Activity	- Schenkel (1995)	1991 EC (1994b)[1]	1992 FAO (1994)	1987 Hall *et al.* (1994)	1992 UN (1994a)
Residential use	-	8.0	-	-	-
Industrial use	-	0.4	-	-	-
Pulp & paper industry	5.4	-	-	-	-
Fuel wood	7.1[2]	-	5.9[4]	6.0	5.4[4]
Others	-	6.0[3]	-	-	-
Total use	12.5	14.4	-	-	-

[1] Refers to wood, wood waste and other solid waste but excluding municipal solid waste and includes Luxembourg.
[2] Refers to households and small wood industries.
[3] Refers to power stations.
[4] Refers to the description in Chapter 1.

Potential use of biomass for energy

There is a lack of information on the potential use of biomass for energy in Belgium and Luxembourg. Caserta (1994) estimates 21 PJ. Regarding the additional potential of wood for energy statistics by Pajuoja (1995) estimate a constant unused timber resource of 8 PJ.

Table 2.12. Potential use of wood derived biomass for energy production in Belgium and Luxembourg in PJ.

Activity / Source	Caserta (1994)	Pajuoja (1995)
Additional harvesting	-	8
Forest residues	17.0	-
Waste wood	-	-
Fuel wood	-	-
Non-forest wood	-	-
Industrial residues	4.0[1]	-
Technical potential	21.0	-

[1] The given potential is already partially used.

2.2.7. DENMARK

Current use of biomass for energy

Although the forest area of the Danish total land area (0.5 million ha or 12 %) is far below the European average, some 6 % of the primary energy consumption (754 PJ) is supplied by biomass (Mosbech, 1994) and 2-4 % by wood and the rest is supplied in the form of straw and waste.

Wood energy contributed by 15 PJ out of 28 PJ bioenergy in 1990 (Ministry of Energy/ Danish Energy Agency, 1992). Evald (1991) estimated that wood energy contributed by 11 PJ out of 22 PJ of all bioenergy consumption. Higher estimates on the wood energy (32 PJ in 1991) have been published by EC (1994b). According to different sources, the fuelwood consumption reaches 5 PJ (FAO, 1994; Hall *et al.*, 1994). Hall *et al.* (1994) present a rather high total use of biomass which is probably due to a high share of agricultural residues, particularly straw and biogas.

Table 2.13. Current use of wood derived biomass for energy production in Denmark in PJ.

Reference year / Source / Activity	1989 Center für Biomasse-Technologie (1993)[1]	1990 Ministry of Energy/DEA (1992)	1990 Evald, (1991)[2]	1991 EC (1994b)[3]	1992 FAO (1994)	1987 Hall *et al.* (1994)
Fuel wood	1.9	8.4[6]	-	-	5.0[4]	5.0
Wood chips	1.3	-	1.7	-	-	-
Wood pellets	2.0	-	1.6	-	-	-
Waste wood, bark	-	6.8	3.3	-	-	-
Residential use	-	-	4.8	14.9	-	-
Industrial use	-	-	-	6.1	-	-
District heating	-	-	-	7.1	-	-
Power industry	-	-	-	3.7	-	-
Total use	5.2	15.2	11.4	31.8	-	84.0[5]

1 Original data given in volume and mass units which are converted by 0.5 t /m^3 and 14 GJ/t, and 20 GJ/t of wood pellets.
2 Refers to the energy sector only.
3 Refers to wood, wood waste and other solid waste but excluding municipal solid waste.
4 Refers to the description in Chapter 1.
5 According to Biomass User Network; includes all forms of biomass consumption for energy in various years in the 1980's.
6 Takes wood chips into account.

Potential use of biomass for energy

In Denmark a progressive energy policy has been enforced for the period 1990 to 2005, known as "Action Plan 2000". Its objective is to reduce the energy consumption by 15 %, but increase the consumption of natural gas and renewable energy carriers by 170 % respectively 100 %. This action is supplemented by specific energy and CO_2 taxes. NUTEK's (1993) assessment identifies 21 PJ of wood energy which could become potentially available. Somewhat less, 17 PJ is suggested by the IEA (1995).

Table 2.14. Potential use of wood derived biomass for energy production in Denmark in PJ.

Source / Activity	IEA (1995)	NUTEK (1993)
Additional harvesting	-	17
Forest residues	13.0	-
Fuel wood	-	4
Non-forest wood	-	-
Industrial residues	4.0[1]	-
Technical potential	17.0	21

[1] The given potential is already partially used.

2.2.8. *FRANCE*

Current use of biomass for energy

After Spain, France is expected to achieve the highest annual increase in forest area in Europe with some 44,000 ha annually until 2020 (Nilsson *et al.*, 1992a). This contributes to the existing 14.6 million ha of the forests, which cover 27 % of the land area. The country has a population of 57.4 million and a wood energy production which amounts to 5 % (EC 1994c) of the total energy consumption (9,286 PJ).

Data presented on the wood-based energy consumption by Agence Francaise pour la Maitrise de l'Energie (1989) and Morin and Laufer (1992) are fairly consistent, 397 respectively 385 PJ. While Barbier and Radanne (1994) presented a somewhat smaller estimate of 368 PJ, the Statistical Office of the European Communities states that the use of wood, wood waste and other solid waste excluding municipal solid waste contributed by 407 PJ to the primary energy production in 1991. Wood energy consumption for residential use is estimated to 335-345 PJ (EC, 1994b; Agence Francaise pour la Maitrise de l'Energie,1989).

Fuelwood only contributes by 95-112 PJ (FAO, 1994; Hall *et al.*, 1994) to the energy consumption. This estimate does probably not take into consideration non-economic fuelwood consumption in rural areas. Statistical data of the French pulp and paper industry identify 10 PJ of energy produced for industrial use by alternative sources in 1993. Hall et al. (1994) assumed that the use of all forms of biomass for energy production amounted to 315 PJ in 1987.

Table 2.15. Current use of wood derived biomass for energy production in France in PJ.

Reference year / Source / Activity	1989 Agence Francaise pour la Maitrise de l'Energie (1989)[1]	- Barbier and Radanne (1994)[1]	- Morin and Laufer (1992)[1]	1993 COPACEL (1994)	1991 EC (1994b)[2]	1992 FAO (1994)	1987 Hall *et al.* (1994)
Residential use	334.9	-	334.9	-	344.8	-	-
Industrial use	-	-	-	-	58.1	-	-
Pulp & paper industry	46.1	-	46.1	10.1[3]	-	-	-
Fuel wood	-	-	-	-	-	94.5[5]	112.0
Others	15.5[7]	-	4.2[7]	-	4.1[4]	-	-
Total use	396.5	368.4	385.2	-	407.0	-	315.0[6]

[1] Original data (million Toe) converted by 41.868 PJ/million Toe according to Kaltschmitt and Wiese (1993).
[2] Refers to wood, wood waste and other solid waste but excluding municipal solid waste.
[3] Refers to other energy sources than coal, oil, gas and electricity (1 Thermie = $4.1855*10^6$ J after La Grande Encyclopédie Larousse, 1972).
[4] Refers to district heating.
[5] Refers to the description in Chapter 1.
[6] According to Biomass User Network; includes all forms of biomass consumption for energy in various years in the 1980's.
[7] Refers to other sources than forestry and wood processing industry.

Potential use of biomass for energy

Limited information is available on the French biomass energy potential. NUTEK (1993) suggests that the forest fuel potential from unused forest increments, industrial residues and fuelwood amounts to 189, 103, and 92 PJ respectively and add up to 384 PJ. IEA (1995) estimates the biomass energy potential to be 347 PJ.

Table 2.16. Potential use of wood derived biomass for energy production in France in PJ.

Reference year / Source / Activity	IEA, 1995	NUTEK, 1993
Additional harvesting	-	189
Forest residues	293	-
Waste wood	-	-
Fuel wood	-	92
Non-forest wood	-	-
Industrial residues	54[1]	103
Technical potential	347	384

[1] The given potential is already partially used.

2.2.9. GERMANY

Current use of biomass for energy

Germany is covered by 10.4 million ha or by 30 % of forests. Although Germany is a major consumer of wood, the actual share of wood-based fuels have of primary energy consumption (13,980 PJ) is rather small (0.3-0.7%). This is likely the reason for the limited availability of information on current bioenergy production from the forest sector.

The EC report on renewable energy resources (1994b) states that 97 PJ of wood and wood waste derived energy was produced in Germany. Wintzer et al. (1993) estimate the 1990 biomass use for primary energy use to be 50 PJ. FAO (1994) describes the fuelwood use to be 46 PJ in 1992. Hall *et al.* (1994) present the same figure. The annual report 1994 of the German Association of Paper Factories (VDP, 1994) provides data on industrial energy production from forest biomass: pulping liquors 11 PJ, bark 1 PJ, sludge 1 PJ, waste paper residues 1 PJ and other residues 1 PJ, adding up to 16 PJ in 1993.

Table 2.17. Current use of wood derived biomass for energy production in Germany in PJ.

Reference year / Source / Activity	1990 Wintzer *et al.* (1993)	1991 EC (1994b)[1]	1992 FAO (1994)	1987 Hall *et al.* (1994)	1991 VDP (1994)
Fuelwood	-	-	46.1[2]	46.0	-
Residential use	-	92.2	-	-	-
Industrial use	-	4.7	-	-	15.8
Total use	49.8[3]	96.9	-	84[4]	-

[1] Refers to wood, wood waste and other solid waste but excluding municipal solid waste.
[2] Refers to the description in Chapter 1.
[3] Refers to primary energy demand based on biomass.
[4] According to Biomass User Network; includes all forms of biomass consumption for energy in various years in the 1980's.

Potential use of biomass for energy

The most detailed analysis of the technical wood based energy potential suggests a potential of 142 PJ annually. This would correspond to 1.5 % of the national energy consumption and 2.4 % of the national energy use for residential heating and process heating in 1991 (Kaltschmitt and Wiese, 1993). This potential is constituted by forest residues from harvesting (115.5 PJ) and biomass from additional thinnings (26.2 PJ). While the Forestry

Test and Research Institute of Baden-Württemberg (Fischer, 1994) presented the wood potential for energy production to be 122.5 PJ, Burschel *et al.* (1993) and Marutzky and Strecker (1994) estimate the potential to be 110.6 PJ respectively 138.2 PJ. The more theoretical approach of NUTEK (1993) presents a potential of 308 PJ while IEA (1995) suggests 256 PJ. Wintzer et al. (1993) define the biomass energy demand to be 293-586 PJ in the year 2005.

Table 2.18. Potential use of wood derived biomass for energy production in Germany in PJ.

Reference year / Source / Activity	Burschel et al. (1993)[1]	Fischer (1994)[1]	Kaltschmitt and Wiese (1993)	Marutzky and Strecker (1994)[3]	2005 Wintzer *et al.* (1993)	IEA (1995)	NUTEK (1993)
Add. harvesting	-	-	-	-	-	-	235
Thinnings[6]	34.1	-	26.2	-	-	-	-
Forest residues	58.3[6]	39.6[6]	115.5[6]	-	-	209.0	-
Waste wood[5]	18.2	21.6	-	65.0	-	-	-
Fuel wood	-	43.2	-	33.6	-	-	43
Industrial residues	-	15.9[6]	-	39.6[6]	-	50.0[7]	30
Others	-	2.2	-	-	-	-	-
Technical potential	110.6	122.5	141.7	138.2	293-586[4]	259.0	308

1 Volume based numbers (oven dry) converted by 0.4 t /m^3 and 18 GJ/t.
2 Mass based numbers converted by 0.4 t /m^3 and footnotes [4] and [5].
3 If not otherwise stated volume based numbers converted by 0.4 t /m^3 and 14 GJ/t.
4 Refers to primary energy demand based on biomass.
5 Volume based numbers converted by 0.4 t /m^3 and 13 GJ/t after Rakos (1993).
6 Volume based numbers converted by 0.4 t/m^3 and 11 GJ/t after Rakos (1993).
7 The given potential is already partially used.

2.2.10. IRELAND

Current use of biomass for energy

Ireland's small share of forest land area (0.4 million ha or 6 % of land area) limits the use of wood for energy utilization to 1 % of the total energy requirements (417 PJ).

EC (1994b) assessed the wood and wood waste for energy production to be 2 PJ for residual use and 2.5 PJ for industrial use adding up to more than 4.5 PJ in 1991. FAO (1994) suggests 0.5 PJ of woodfuel use and Hall et al. (1994) 46 PJ of all forms of biomass consumption for energy production.

Table 2.19. Current use of wood derived biomass for energy production in Ireland in PJ.

Reference year / Source / Activity	1991 EC (1994b)[1]	1992 FAO (1994)	1987 Hall *et al.* (1994)
Residential use	1.9	-	-
Industrial use	2.5	-	-
Pulp & paper industry	-	-	-
Fuel wood	-	0.5[2]	-
Others	-	-	-
Total use	4.4	-	46.0[3]

1 Refers to wood, wood waste, and other solid waste but excluding municipal solid waste.
2 Refers to the description in Chapter 1.
3 According to Biomass User Network; includes all forms of biomass consumption for energy in various years in the 1980's.

Potential use of biomass for energy

There is only one assessment available (NUTEK, 1993), which suggests the potential of woodfuel use might double to 8 PJ.

Table 2.20. Potential use of wood derived biomass for energy production in Ireland in PJ.

Reference year / Source / Activity	NUTEK, 1993
Additional harvesting	8
Forest residues	-
Waste wood	-
Fuel wood	0
Non-forest wood	-
Industrial residues	0
Technical potential	8

2.2.11. ITALY

Current use of biomass for energy

Italy has a population of 57.9 million, a forest area of 6.8 million ha (23 % of the land area), and a wood energy consumption of some 2 % of the primary energy consumption (6,500 PJ).

A major share of the wood based energy consumption occurs in the wood processing industry (Caserta, 1994; EC, 1994b). But the far most important consumer of woodfuel energy is the residential sector (Caradini, 1994; EC, 1994b). Total wood energy consumption ranges between 82-152 PJ during the recent years (Caradini, 1994; EC, 1994b, *Hall et al.*, 1994).

Table 2.21. Current use of forest biomass for energy production in Italy in PJ.

Reference year / Source / Activity	1993 Caradini (1994)	Caserta (1994)[1]	1991 EC (1994b)[2]	1992 FAO (1994)	1987 Hall *et al.* (1994)
Residential use	-	75.4	90.0	-	-
Industrial use	-	-	24.0	-	-
Pulp & paper industry	6.5	-	-	-	-
Fuel wood	-	-	-	54.5[5]	48.0
Wood residues	-	6.7[3]	-	-	-
Others	-	-	1.0[4]	-	-
Total use	-	82.1	115.0	-	151.0[6]

[1] Original data (millionToe) converted by 41.868 PJ/million Toe according to Kaltschmitt and Wiese (1993).
[2] Refers to wood, wood waste, and other solid waste but excluding municipal solid waste.
[3] Refers to energy use of residues from wood manufacturing industries.
[4] Refers to power stations.
[5] Refers to the description in Chapter 1.
[6] According to Biomass User Network; includes all forms of biomass consumption for energy in various years in the 1980's.

Potential use of biomass for energy

While NUTEK (1993) suggests a rather high woodfuel potential of 344 PJ, Caserta (1994) presents a potential of 180 PJ. Most of this latter potential derives from forest residues. The potentials for industrial wood residues correspond in the two assessments.

Table 2.22. Potential use of wood derived biomass for energy production in Italy in PJ.

Reference year / Source / Activity	Caserta (1994)	NUTEK (1993)
Additional harvesting	-	282
Forest residues	163.0	-
Fuel wood	-	42
Non-forest wood	-	-
Industrial residues	17.0[1]	19
Technical potential	180.0	344

[1] The given potential is already partially used.

2.2.12. THE NETHERLANDS

Current use of biomass for energy

In the Netherlands the forest area accounts to 9 % of the total land area (0.3 million ha) and the population is 15.2 million inhabitants. Despite intensive afforestations the domestic wood fuel resource is limited. Biomass energy and wood-based energy covers approximately 1 % respectively 0.2-0.8 % of the primary energy consumption (2,881 PJ) in the Netherlands (Faaij, 1994).

As seen by the following references waste wood and fuelwood are the most important biomass fractions for energy production besides general waste. According to the EC (1994b), 39 PJ were generated from biomass and wastes in 1991 of which 15 PJ was generated by fuelwood in households and 2 PJ in the form of wood and wood wastes in the wood, furniture and paper industry. The production figures for wood energy published by Van Zanten (1994), Kwant (1994, 1996), De Vos (1994), and Faaij (1994) range between 15 and 24 PJ for 1992 and up to 35 PJ for 1994. Sikkema (1993) has estimated the use of roundwood, residues and waste wood in 1992 for energy production to 4 PJ. FAO's fuelwood statistics (1994) estimate some 3 PJ. The fuelwood usage for energy is estimated by Hall *et al.* (1994) to 1 PJ.

Table 2.23. Current use of wood derived biomass for energy production in the Netherlands in PJ.

Ref. year / Source / Activity	1992 Van Zanten (1994)	1992 Kwant (1994)	1994 Kwant (1996)	1992 De Vos (1994)	1992 Faaij (1994)	1991 EC (1994b)[1]	1987 Hall *et al.* (1994)[2]	1992 FAO (1994)
Fuelwood	-	9.0	-	-	-	-	1.0	3.1[7]
Residential use	-	-	-	-	15.7	15.0	-	-
Chips, etc.	-	2.4	-	-	-	-	-	-
Waste wood[3]	10.0	0.3	-	-	-	-	-	-
Pulping/ industrial use	-	0.1	-	-	1.8	-	-	-
Others	5.0[5]	12.4[5]	-	-	2.6[6]	-	-	-
Total use	15.0	24.2	35,2[8]	20[4]	18.3	16.8	-	-

[1] Refers to wood, wood waste, and other solid waste but excluding municipal solid waste.
[2] According to Biomass User Network; includes all forms of biomass consumption for energy in various years in the 1980's.
[3] Includes demolition wood only.
[4] Energy content of 8 GJ/t at 50 % moisture content (Hakkila, 1985).
[5] Refers to waste incineration.
[6] Refers to the industrial combustion of waste and biomass.
[7] Refers to the description in Chapter 1.
[8] Refers to biomass and waste.

Potential use of biomass for energy

Present plans aim at a 4 % share for biomass energy of the primary energy use in the Netherlands (Faaij, 1994). Furthermore, in the same reference the maximum contribution by biomass energy is given to some 8 %, with the assumption that all available arable land (500.000 ha) is used for energy crops. The theoretical biomass energy potential is given to 23 PJ, of which 16 PJ could be derived by increased wood removals (NUTEK, 1993).

The Netherlands imported wood and paper to a value of US$ 4,600 million in 1992 (FAO, 1994). An enhanced reuse of waste wood is suggested (Sikkema, 1993). Sikkema (1993) estimates a 3 PJ increase in wood energy utilization in the near future. This deviates from the plan to use residues and waste wood by an additional 5 PJ/year and the planned expansion of forests to generate additional 8 PJ annually. Sikkema (1993) estimates the unused waste wood energy potential to 26 PJ based on the 1990 wood consumption.

Kwant (1994) and De Vos (1994) suggest 39 PJ respectively 54-60 PJ as wood energy potentials. Faiij (1994) estimates an availability of 26-30 PJ of the total potential of 73-78 PJ in the Netherlands. The difference between the availability and the total potential is used in alternative development options. Additionally, Kwant (1994) estimates that 140 PJ could be generated by energy plantations. Kwant (1996) concludes that the renewable energy targets from biomass and waste described are 83 and 270 PJ in year 2000 and in year 2020 respectively. IEA (1995) suggests that 8 PJ of energy stem from forestry and timber industry residues.

Table 2.24. Potential use of wood derived biomass for energy production in the Netherlands in PJ.

Reference year / Source / Activity	Sikkema (1993)	Kwant (1994)	2000/2020 Kwant (1994)	2000/2010 De Vos (1994)	Available Faaij (1994)	IEA (1995)	NUTEK (1993)
Add. thinnings	-	-	-	-	9.0-10.0	-	16
Round wood	7.4	20.8	-	-	-	-	-
Residues	3.6	3.6	-	-	2.4-3.6	8.0[7]	5
Wood chips	0.7	-	-	-	0.8[1]	-	-
Fuelwood	-	-	-	-	-	-	2
Waste wood	14.1	14.8	-	-	7.4-8.6	-	-
Others	-	51.4[4]	-	-	6.7[5]	-	-
Technical potential	25.8	90.6[6]	83/270[8]	54/60[3]	26.3-29.7	8.0	23

[1] Described as industrial waste wood.
[2] Described as energy crops grown in plantations with poplar, willows and Miscanthus.
[3] Includes waste and biomass.
[4] Refers to waste inceneration.
[5] Refers to waste paper.
[6] Includes waste incineration.
[7] Refers to forest residues.
[8] Refers to biomass and waste.

2.2.13. UNITED KINGDOM

Current use of biomass for energy

Great Britain's forest area is 2.4 million ha, representing some 10 % of the total land area. Currently 0.1-0.2 % of the primary energy consumption (8,967 PJ) is provided by wood energy (EC, 1994b). Although there are considerable efforts to increase the share of renewable energy carriers there is little information available on energy derived from wood.

According to ETSU (1994) 1.06 million tons of wood was almost exclusively used as firewood in 1989. EC (1994b) states that 7 PJ of wood and wood waste were used in households and 3 PJ in industry, summing up to 10 PJ in 1991. According to Hall *et al.* (1994) the fuelwood consumption was 2 PJ in 1987 which shows a considerable lower use than potential demands by a population of 58 million people (EC, 1994a). FAO (1994) estimates the fuelwood consumption in 1992 to be 3.6 PJ.

Table 2.25. Current use of wood derived biomass for energy production in the United Kingdom in PJ.

Reference year / Source / Activity	1989 ETSU (1994)	1992 FAO (1994)	1991 EC (1994b)[1]	1987 Hall *et al.* (1994)
Fuelwood	14.8[2]	3.6[3]	-	2.0
Residential use	-	-	6.8	-
Industrial use	-	-	3.1	-
Waste wood	-	-	-	-
Waste paper	-	-	-	-
Total use	-	-	9.9	46[4]

[1] Refers to wood, wood waste and other solid waste but excluding municipal solid waste.
[2] Mass-based numbers converted by 14 GJ/t..
[3] Refers to the description in Chapter 1.
[4] According to Biomass User Network; includes all forms of biomass consumption for energy in various years in the 1980's.

Potential use of biomass for energy

NUTEK (1993) mentions 108 PJ to be UK's forest fuel potential of which 101 PJ could origin from unused forest increment. Mitchell *et al.* (1990) presents two assessments; the one for 1989 suggests 19 PJ from thinnings and 15 PJ from forest residues which adds up to 34 PJ and another one for 2010 where thinnings and forest residues could amount to 26 PJ and 16 PJ respectively, totaling 42 PJ. ETSU (1994) suggests 5-6.5 PJ of practical available forestry wastes for energy production of a total accessible wood energy of 14-18 PJ in the years 2005 and 2025. IEA (1995) estimates 37 PJ as a technical potential.

Table 2.26. Potential use of wood derived biomass for energy production in the United Kingdom in PJ.

Reference year / Source / Activity	2005 ETSU, 1994	2025	1989 Mitchell *et al.* (1990)[1]	2010	IEA, 1995	NUTEK, 1993
Add. harvesting	-	-	-	-	-	101.0
Thinnings	-	-	18.9	25.8	-	-
Fuelwood	-	-	-	-	-	2.0
Forest residues	14.0[2]	18.0[2]	15.3	16.2	29.0	5.0
Industrial residues	-	-	-	-	8.0[3]	-
Technical potential	-	-	34.2	42.0	37.0	108.0

[1] Mass based number (3.26 green tons in 1989; 4.0 green tons in 2010) converted by 10.5 GJ/t at 40 % moisture content (Hakkila, 1989).
[2] Original numbers (in TWh/y) converted by a factor of 3.6 to PJ.
[3] The given potential is already partially used.

2.2.14. ALBANIA

Due to the fact that there is only limited information available Albania is considered in Chapter 2.2.20.

2.2.15. GREECE

Current use of biomass for energy

Greek forests cover 2.6 million ha (20 % of the land area) and some 6.5 % of the energy requirements are covered by woodfuels. According to Nilsson *et al.* (1992a), NUTEK (1993) and Table 2.1. there are little resources left for increased timber harvests. Therefore, the development of the woodfuel production can not be expected to keep up with future increased energy demands (in 1992 924 PJ). EC (1994b) suggests less than 59 PJ of wood based energy consumption while Hall *et al.* (1994) present an estimate of 42 PJ and FAO (1994) 14 PJ for fuelwood only.

Table 2.27. Current use of wood derived biomass for energy production in Greece in PJ.

Reference year Source Activity	1991 EC (1994b)[1]	1992 FAO (1994)	1987 Hall *et al.* (1994)
Residential use	53.5	-	-
Industrial use	5.0	-	-
Pulp & paper industry	-	-	-
Fuel wood	-	14.0[2]	23.0
Others	-	-	-
Total use	58.5	-	42.0[3]

[1] Refers to wood, wood waste, and other solid waste but excluding municipal solid waste.
[2] Refers to the description in Chapter 1.
[3] According to Biomass User Network; includes all forms of biomass consumption for energy in various years in the 1980's.

Potential use of biomass for energy

The potential for fuelwood use is estimated to be 25- 30 PJ (Caserta, 1994; NUTEK, 1993).

Table 2.28. Potential use of wood derived biomass for energy production in Greece in PJ.

Reference year / Source / Activity	Caserta, 1994	NUTEK, 1993
Additional harvesting	-	9
Forest residues	21	-
Waste wood	-	-
Fuel wood	-	19
Non-forest wood	-	-
Industrial residues	4[1]	2
Technical potential	25	30

[1] The given potential is already partially used.

2.2.16. PORTUGAL

Current use of biomass for energy

In Portugal the forest area accounts to 3 million ha or 33 % of the total land area. A population of 9.8 million consumed 699 PJ of primary energy and of which energy from wood and other solid waste contributed by 91 PJ or 14 % (EC, 1994b). Portugal faces a conditions as other southern European countries, such as Albania, Cyprus, Greece and parts of former Yugoslavia: the felling/increment ratio is higher than the European average and is over 95 % (UN, 1996a). Fuelwood and charcoal consumption is estimated to be 14-23 PJ in Portugal (FAO, 1994; Hall et al., 1994).

Table 2.29. Current use of wood derived biomass for energy production in Portugal in PJ.

Reference year / Source / Activity	1984 FBVA (1996)	1991 EC (1994b)[1]	1992 FAO (1994)	1987 Hall *et al.* (1994)
Residential use	4.8	61.3	-	-
Industrial use	14.5	22.2	-	-
Pulp & paper industry	-	-	-	-
Fuel wood	-	-	4.8[3]	6.0
Others	-	7.8[2]	-	-
Total use	19.3	91.3	-	34.0[4]

[1] Refers to wood, wood waste, and other solid waste but excluding municipal solid waste.
[2] Refers to power stations.
[3] Refers to the description in Chapter 1.
[4] According to Biomass User Network; includes all forms of biomass consumption for energy in various years in the 1980's.

Potential use of biomass for energy

Caserta (1994) estimates the potential for wood energy to be 71 PJ and most of it in the form of forest residues. NUTEK (1993) presents a rather optimistic potential of 124 PJ, which may be an overestimation.

Table 2.30. Potential use of wood derived biomass for energy production in Portugal in PJ.

Source / Activity	Caserta (1994)	NUTEK (1993)
Additional harvesting	-	94
Forest residues	59.0	-
Waste wood	-	-
Fuel wood	-	5
Non-forest wood	-	-
Industrial residues	13.0[1]	25
Technical potential	71.2	124

[1] The given potential is already partially used.

2.2.17. SPAIN

Current use of biomass for energy

Spain is inhabited by a population of 39.1 million and consumes 3,844 PJ of primary energy. The forest land area is 15.9 million ha or 32 % of the total land area. Some 4 % of the primary energy consumption stemmed from wood and solid waste energy (156 PJ) in 1991 (EC, 1994b).

Table 2.31. Current use of wood derived biomass for energy production in Spain in PJ.

Reference year / Source / Activity	1991 EC (1994b)[1]	1992 FAO (1994)	1987 Hall *et al.* (1994)
Residential use	87.3	-	-
Industrial use	68.3	-	-
Pulp & paper industry	-	-	-
Fuel wood	-	14.7[3]	25.0
Others	0.5[2]	-	-
Total use	156.1	-	40.0[4]

[1] Refers to wood, wood waste, and other solid waste but excluding municipal solid waste.
[2] Refers to power stations.
[3] Refers to the description in Chapter 1.
[4] According to Biomass User Network; includes all forms of biomass consumption for energy in various years in the 1980's.

Potential use of biomass for energy

Limited information is available on the potential for wood energy. Caserta (1994) and NUTEK (1993) estimate 100 PJ respectively 133 PJ.

Table 2.32. Potential use of wood derived biomass for energy production in Spain in PJ.

Source / Activity	Caserta (1994)	NUTEK (1993)
Additional harvesting	-	78
Forest residues	80.0	-
Waste wood	-	-
Fuel wood	-	15
Non-forest wood	-	-
Industrial residues	20.0[1]	40
Technical potential	100.0	133

[1] The given potential is already partially used.

2.2.18. TURKEY

Current use of biomass for energy

Forests cover an area of 20.2 million or 27.5 % of the total land area. With a population of 58.8 million and a primary energy consumption of 2,325 PJ, wood is utilized for energy purposes in the range of 4-5 % of the total energy consumption. Estimations on biomass energy are rather consistent and are in the range of 95-116 PJ (FAO, 1994; FBVA, 1996; Hall et al., 1994).

Table 2.33. Current use of wood derived biomass for energy production in Turkey in PJ.

Reference year	-	1992	1987
Source / Activity	FBVA (1996)	FAO (1994)	Hall *et al.* (1994)
Residual use	-	-	-
Industrial use	-	-	-
Pulp & paper industry	-	-	-
Fuel wood	-	94.7[1]	113.0
Others	-	-	-
Total use	116.2	-	n.a.[2]

[1] Refers to the description in Chapter 1.
[2] Not available.

Potential use of biomass for energy

The potential consumption of biomass energy is estimated to be 247-258 PJ (Caserta, 1994; NUTEK, 1993).

Table 2.34. Potential use of wood derived biomass for energy production in Turkey in PJ.

Source / Activity	Caserta (1994)	NUTEK (1993)
Additional harvesting	-	164
Forest residues	197.0	-
Waste wood	-	-
Fuel wood	-	92
Non-forest wood	-	-
Industrial residues	50.0[1]	2
Technical potential	247.0	258

[1] The given potential is already partially used.

2.2.19. FORMER YUGOSLAVIA

Due to the fact that there is only limited information available, Former Yugoslavia is considered in Chapter 2.2.20.

2.2.20. EASTERN EUROPE

There is limited information available on country level for the Baltic countries and EasternEurope. The same is true for Albania and Former Yugoslavia that is why these two countries are delt with in this chapter. Cited figures derive from statistics from the CEC (1994b), the FAO (1995) and UN (1994b; 1996). When adding the population of the Baltic countries to Eastern Europe some 104 million inhabitants have to be considered which consumed 11,179 PJ of primary energy in 1992. Wood energy production is estimated to 145-168 PJ in 1992 which corresponds to 1.3-1.5 % of the total energy production. This low level likely does not include the non-economic use of wood for energy production.

Table 2.2.35. Current and potential use of wood derived biomass for energy production in Eastern Europe in PJ.

Country Reference year	Primary energy consumption[1] 1992	Current wood-based energy production[2] 1992	Potential wood-energy use[3] low	 high
Albania	62.8	16.3	20.9[7]	23.6[8]
Former Yugoslavia	1385.8	33.3	42.3[7]	47.6[8]
EASTERN EUROPE				
Bulgaria	770.4	19.8	19.8[5]	21.0[6]
Former Czechoslovakia	2373.9	13.4	13.4[5]	14.2[6]
Estonia	251.2	8.5	15.0[9]	15.0[9]
Hungary	1084.4	23.3	23.3[5]	24.6[6]
Latvia	334.9	7.4	13.0[9]	13.0[9]
Lithuania	460.5	10.5[4]	18.5[9]	18.5[9]
Poland	3981.6	33.8	33.8[5]	35.7[6]
Romania	1921.7	28.3	28.3[5]	29.9[6]
TOTAL EASTERN EUROPE	11178.6	145.0	165.1	175.1
Eastern Europe (UN, 1996)	-	168.0	168.0	196.0

[1] EC (1994a).
[2] FAO (1995). Original figures converted by 0.75 tons/m^3 and by 14 GJ/ton.
[3] Refers up to year 2020.
[4] Figure taken from UN (1994b) country profil for 1990. Only the number for deciduous pulpwood/ fuelwood (1 million m^3) is assumed to serve as fuelwood.
[5] UN's (1996) estimate of no increase in the "low" forecast for Eastern Europe is employed.
[6] UN's (1996) estimate of an increase by 0.2 % per year in the "high" forecast for EasternEurope is employed.
[7] UN's (1996) estimate of an increase by 0.8 % per year in the "low" forecast for South EasternEurope is employed.
[8] UN's (1996) estimate of an increase by 1.2 % per year in the "high" forecast for South EasternEurope is employed.
[9] UN's (1996) estimate of an increase by 1.9 % per year in the "low" and "high" forecast for the Baltic countries is employed.

Up to 2020 the UN (1996) estimates the increase in the supply of wood energy to 0-0.2 % per year in their "low" and "high" forecast for EasternEurope and the Baltic countries. While for South EasternEurope the increases are estimated to 0.8 % and 1.2 % per year, the wood energy supply in the Baltic countries will prosper at 1.9 % per year until year 2020. The outlook for fuelwood consumption in transition economies in East, South EasternEurope, and the Baltic States foresees an average increase in the magnitude of 0.4 % per year until 2020. The potential of wood energy use is estimated to 165-175 PJ in year 2020.

2.3. FOREST BIOMASS POTENTIALS OF EUROPE

2.3.1. GROWING FOREST STOCK IN EUROPE

Pajuoja (1995) assumes a constantly increased forest area in Europe. This trend linked with annual fellings that are lower than net annual increment rates result in an accumulation of growing stocks. For year 2050 he forecasts an increase of the growing stock by 58 %, from today's 20 billion m^3 to nearly 31.5 billion m^3.

Table 2.3.1. Growing stock in Europe under current trends up to 2050 (extrapolated from Pajuoja, 1995).

	1990		2020		2050	
	[mill. m^3]	[EJ]	[mill. m^3]	[EJ]	[mill. m^3]	[EJ]
Growing stock	19967.8	139.8[1]	25421.2	177.9[1]	31464.1	220.2[1]

[1] 1 ton of wood at 14 GJ/ton is assumed to be made up by 2 m^3.

Nilsson et al. (1992a) made forecasts on the future harvesting possibilities and the development of the growing stock in Europe. The latter harvesting possibilities are higher than Pajuoja's felling rates and in the base scenario the growing stock is foreseen to develop from the current 17 billion m^3 to 21 billion m^3 (+23 %) by year 2050.

Table 2.3.2. Growing stock in Europe under the basic and forest land expansion scenarios (interpolated from Nilsson et al., 1992a).

	2020		2050		2100	
[mill. m^3]	Basic	Expansion	Basic	Expansion	Basic	Expansion
Growing stock [in mill. m^3] [in EJ][3]	19121.4[1] *133.8*	20575.0[2] *144.0*	20958.4[1] *146.7*	22471.4[2] *157.3*	24020.1[1] *168.1*	25632.2[2] *179.4*

[1] Assuming a constant land area of exploitable closed forests of 139.166 mill. ha. Excludes the Baltic States and Albania.
[2] Assuming a constant land area of exploitable closed forests of 150,512 mill. ha beyond 2020. Excludes the Baltic States and Albania.
[3] 1 ton of wood at 14 GJ/ton is assumed to be made up by 2 m^3.

2.3.2. FELLINGS IN EUROPE

Pajuoja (1995) analyses the trends in the development of the European forest resources and roundwood supply and the analyses are based on the assessment 1990 UN-ECE/FAO forest resources. He concludes that the forest land area has increased by about 2 million ha during the last decade while a unused forest resources (the difference between the net annual increment (NAI) and annual fellings) amounts currently to 43 %.

As shown in the base scenario of Pajuoja (1995) the trends of increased forest land areas and unused forest reserves are expected to continue. The difference between fellings and NAI is estimated to be 190 million m^3 around year 2040. This is remarkable due to the fact that he also estimates increased fellings by a magnitude of 20 % (from 439 million m^3 in 1990 to 497 million m^3 in 2040). In order to estimate the development of the forest resource up to 2050 the prescribed trends is extrapolated (Table 2.3.3.).

Table 2.3.3. Area of exploitable forest land, fellings under bark and net annual increment (NAI) for European sub-regions under suggested trends up to 2050 (extrapolated from Pajuoja, 1995).

	1990 [mill. ha]		2020 [mill. ha]		2050 [mill. ha]	
Forest land area	140.4		145.1		149.0	
	[mill. m^3]	[PJ]	[mill. m^3]	[PJ]	[mill. m^3]	[PJ]
NAI[1]	629.8	4408.6	696.2	4873.4	741.3	5189.1
Fellings						
Baltic	12.9	90.3	19.9	139.3	19.8	138.6
Nordic	131.6	921.2	130.9	916.3	122.0	854.0
Central	26.1	182.7	28.7	200.9	32.8	229.6
East	70.9	496.3	78.8	551.6	83.6	585.2
EU-12	160.9	1126.3	195.8	1370.6	221.4	1549.8
South-East	36.9	258.3	43.3	303.1	45.4	317.8
Total fellings	439.3	3075.1	497.4	3481.8	525.0	3675.0

[1] NAI = Net annual increment

Nilsson et al. (1992a) published information on the future forest resources of Western and Eastern Europe based on analyses of a the so-called Basic Handbook scenario, which takes ideal silvicultural programs proposed by national authorities into account. While Pajuoja

(1995) recognizes the new European order of nations, Nilsson et al. (1992a) did not include the Baltic states, Albania and Israel in Europe and referred to Germany and the Czech and Slovak Republic as they were constituted before 1990. The basic scenarios developed had 1985 as the starting point and a time horizon of 100 years. Table 2.3.4. displays the interpolated figures for potential fellings in 2020 and 2050 and their extrapolation up to year 2100 under the basic and forest land expansion scenarios.

Table 2.3.4. Potential fellings in Europe under the basic and forest land expansion scenario[1] (interpolated from Nilsson et al., 1992a).

	2020		2050		2100	
[mill. m^3]	Basic	Expansion	Basic	Expansion	Basic	Expansion
Nordic	154.1	158.7	160.6	164.4	165.1	166.4
Central	24.8	25.2	25.1	25.9	25.1	26.5
EU-9	153.3	169.0	153.2	182.4	145.3	192.4
Southern	76.5	81.0	80.9	88.1	87.8	94.7
Eastern	128.2	130.0	128.4	130.4	125.4	128.6
Total fellings	536.9	563.9	548.2	591.2	548.7	608.6
Heating value [PJ]	3758	3947	3837	4138	3841	4262

[1]Excludes the Baltic States and Albania.

In a later study, Nilsson (1996) presents figures on the estimated availability of roundwood (413-451 million m^3) and of which industrial roundwood accounts for 343-421 million m^3 in East, West and Nordic Europe in 2020. He concludes that additional 65 to 103 million m^3 (plus 19-29%) may become available. These latter estimates on the availability are of course over than the potential harvesting levels presented by Nilsson et al. (1992a).

2.3.3. THE BIOENERGY POTENTIAL OF EUROPE

Statistics does not always indicate clearly whether information given on fuelwood consider only wood that is produced and consumed for the sole purpose of energy production. In many cases wood which is burned as a by-product is not taken into account. CEC (1991) has published a study on renewable energy in Europe presented forecasts up to 2010. It presents estimates on biomass used for energy production as well as its market penetration rather than defining the actual biomass resource.

Woodfuel is ascribed to be one of the largest existing renewable energy sources in the EU and is currently consumed to an extent of some 712 PJ. The report (CEC, 1991) lists some 38.2 million tons of forest residues used per year but obviously does not include the forest biomass and wood fiber by-products that are accounted for in industrial solid waste (126.6 million t) and liquid waste (40.8 million t). Furthermore, the theoretical land area available for energy crops is assumed to be 2,200 million ha. For EasternEurope, the woodfuel supply is estimated to be 168 PJ per annum at an availability of 17 million tons of forest residues. For this region the potential land area for energy crops is estimated to 305 million ha.

CEC (1991) concludes that market penetration of renewable energy will be limited and will reach some 6.5 % in the EC-12 market and about 5 % of the primary energy consumption in Central and Eastern Europe by 2010. Under the ECEC's already proposed policies (ALTERNER and carbon tax), this share is expected to rise to 9 % of the EC's total primary energy and to over 13 % when energy prices are adjusted to reflect their full social cost. While other renewable energy sources, such as wind, are estimated to grow most rapidly in the beginning, wood crops and liquid biofuels will become significant only after year 2000 and with the greatest potential for continued penetration after 2010.

In Nilsson (1996) a global shortage of fuelwood and charcoal is indicated which will limit socioeconomic development in developing countries. For Europe he has presented a forecasted fuelwood use of 70 million m^3 in the year 2020, which is an increase by 19 % since 1993. FAO (1995) describes the 1993 fuelwood production with 51 million m^3 plus an import-export balance of nearly 1 million m^3. The reason for the difference between Nilsson's (1996) and the FAO's (1995) figure is that the FAO does not include all countries in their estimate. These as well as CECs' numbers obviously underestimate the total wood consumption (including by-products) for energy production.

The latest European Timber Trend Study V (UN, 1996) presents rather detailed numbers on fuelwood consumption in Europe as well as an outlook till 2020. It refers to wood energy consumption in 1990 and to wood energy supply by means of scenarios. Over 45 % of the volume of wood which is removed annually is aimed to be used for energy production. The 1990 consumption of wood for energy (including by-products) is given to 208 million m^3 or 1,456 PJ (at 7 GJ/m^3). Up to year 2020 the increase in consumption will be modest, 0.8 and

1.5 % per year depending on *low* or *high* scenario and resulting in a total wood energy supply of 265 or 325 million m^3.

Table 2.3.5. The outlook for wood energy in Europe up to 2020 (UN, 1996).

	1990		2020			
	[PJ]	[mill. m^3]	*Low* [PJ]	*Low* [mill. m^3]	*High* [PJ]	*High* [mill. m^3]
Nordic	413	59	462	66	609	87
EU-12	609	87	882	126	1099	157
Central	112	16	119	17	140	20
Eastern& Baltic	168	24	189	27	196	28
South East	161	23	203	29	224	32
Total Europe	1456	208	1855	265	2268	325

2.4. RESOURCES AND POTENTIALS OF *RUSSIA*

Along with the Southern hemisphere Russia's forest reserve is seen to be a crucial region for balancing the global roundwood supply (Nilsson, 1996). In 1990 the Former USSR had a share of the world's industrial roundwood production of 18 % (FAO, 1995) and the area of the global forest resources of nearly one quarter (Backman, 1996). The following information presented for the European and Asian part of Russia refers to growing stock, annual allowable fellings, and bioenergy.

2.4.1. GROWING FOREST STOCK IN RUSSIA

Based on information from the Russian Federal Forest Service (1995) the current biomass resource of Russia has been calculated. Four age classes for coniferous and deciduous tree species, which cover most of of the forests, are accounted for. Isaev et al. (1995) published information on carbon stock and deposition in phytomass of the Russian forests which contains conversion ratios for phytomass carbon. Taken a constant carbon content of forest biomass of 50 %, phytomass conversion factors are applied to IIASA's database information as shown in Table 2.4.1.

Table. 2.4.1. Volume, total biomass and energy content of growing stock in Russia (derived from Russian Federal Forest Service, 1995).

	Coniferous			Deciduous			Total		
	[mill. m³]	[mill. t]	[PJ] [1]	[mill. m³]	[mill. t]	[PJ] [1]	[mill. m³]	[mill. t]	[PJ] [1]
European part	13.350	10.012	140168	8.243	6.652	93128	21.593	16.665	233310
Asian part	49.089	42.311	592354	9.843	7.579	106106	58.932	49.890	698460
Total Russia	62.440	52.323	732522	18.086	14.231	199234	80.526	66.555	931770

[1] An energy content of 14 GJ/t of biomass has been assumed.

Information on total biomass calculated by Isaev et al. (1995) corresponds well with information in Table 2.4.1. Nilsson (1995) indicates that only 61 % of forests under State Forest Management are actually exploitable. Backman (1996) analyses the Russian forest resource and indicates that Russia accounts for 95 % of all the growing forest stock of the former Soviet Union (85.9 billion m^3). In Table 2.4.2. rather new numbers by Lakida et al. (1995; 1996) are presented for growing stock and forest biomass in European Russia and selected countries of the Former European USSR which are similar to the estimates in Table 2.4.1. At the Dialogue in Moscow (1996) "intermediate results" were presented, which estimate the phytomass of the forest vegetation in forested areas of Siberia to 46.5 billion tons.

Table 2.4.2. Aboveground forest biomass of forested areas in selected countries of the Former European USSR and European and Asian Russia (Lakida et al., 1995; 1996; the Dialogue in Moscow, 1996).

	Growing stock [mill. m³]	Aboveground biomass [mill. t]	Energy content [1] [PJ]
European Russia	20278	15465	216510
Baltic States	991	778	10892
Belarus	921	757	10598
Ukraine	1320	957	13398
Moldavia	35	29	406
Georgia	422	331	4634
Armenia	39	35	490
Azerbaijan	128	113	452
Asian Russia, of which	-	46486	650804
West Siberia	-	7639	106946
Eastern Siberia	-	22156	310184
Far East	-	16691	233674
Total Former USSR	-	157923	908184

[1] An energy content of 14 GJ/t of biomass has been assumed.

Nilsson et al. (1992b) present growing stock information on the forest resource of the Former European USSR. The information given for European Russia is consistent with the figure estimated by Lakida et al. (1995), when taking into account that Nilsson et al. (1992b) considered only commercial forests, which corresponds to 68 % of the total forested areas.

Table. 2.4.3. Forecast for the development of the growing stock in commercial forests of the Former European USSR (Nilsson et al., 1992b).

	2020		2050		2100	
	[mill. m^3]	[PJ] [1]	[mill. m^3]	[PJ] [1]	[mill. m^3]	[PJ] [1]
European Russia	14166.9	99168	13602.9	95220	12664.9	88654
Independent states						
Ukraine	752.4	5267	803.9	5627	887.8	6215
Moldavia	12.2	85	12.7	89	13.6	95
Belarus	783.1	5482	811.7	5682	859.4	6016
Baltic States	548.9	3842	564.6	3952	590.7	4135
Former European USSR	16263.5	113844	15795.8	110570	15016.4	105115

[1] An energy content of 7 GJ/m^3 of biomass has been assumed.

2.4.2. FELLINGS IN RUSSIA

Backman (1996) analyses the maximum supportable roundwood supply and estimates that the forest resource of the former USSR supports an annual allowable cut (AAC) of 859 million m^3. The AAC is the average volume of wood that may be harvested annually under sustained yield management. The annual roundwood supply additionally includes intermediate harvests and harvests connected with infrastructure development. Backman (1994) estimates the maximum roundwood supply of Russia to 617 million m^3 (Table 2.4.4.) for the next 20 years. This figure consists of a currently accessible (short to medium term) and potentially accessible (medium to long term) roundwood availability of 417 million m^3 and 200 million m^3 respectively.

Shvidenko and Nilsson (1996) present actual harvesting figures up to 1993, which indicate a constant harvesting level of 300 to 330 million m^3 during 1966-1988 and with a sharp decline in recent years. Nilsson et al. (1994) show for Siberia that the AAC which is given for final fellings and commercial wood from forest land under state forest management, has changed only slightly during 1966-1988 (363 to 386 million m^3). The actual harvest of stemwood from forest land amounted during this period to 29-33 % of the AAC. This information given for 1990 results in an AAC of 382 million m^3 and an actual harvest of 125.6 million m^3.

In Nilsson (1996) the estimated availability of roundwood is suggested to be 285-395 million m^3 of which industrial roundwood and fuelwood amounts to 205-315 million m^3 (175-235 million m^3 for coniferous and 30-80 million m^3 for deciduous) and 80 million m^3 respectively.

Table 2.4.4. Short and medium term accessibility of the Russian forest resource.

	Medium term					
	Conifers		Deciduous		Total	
	[mill. m^3]	[PJ]	[mill. m^3]	[PJ]	[mill. m^3]	[PJ]
Backman (1994)[1]						
European Russia	120	840	126	882	246	1722
Asian Russia	234	1638	137	959	371	2597
Total Russia	354	2478	263	1841	617	4319
Nilsson et al. (1994)[2]						
European Russia	99	695	96	673	196	1369
Asian Russia	221	1547	108	759	329	2306
Total Russia	320	2242	205	1432	525	3674
Nilsson (1996)[3]						
Low	175	1225	30	210	285	1995
High	235	1645	80	560	395	2765

[1] Refers to estimated maximum fiber supply taking intermediate and other utilization into account.
[2] Refers to predicted annual allowable cut by 2010.
[3] Refers to 2020. Totals include 80 million m^3 of fuelwood.

Nilsson et al. (1992b) analyzed the forest resource of the Former European USSR which accounts besides European Russia, Ukraine, Moldavia, Belarus, Estonia, Latvia and Lithuania. They conclude that in the basic scenario there is a slightly increasing potential harvesting level from a sustainable biological point of view over the simulation period of 100 years (from 303 to 325 million m^3).

Table 2.4.5. Potential sustainable biological harvesting levels in the independent states of the Former European USSR (Nilsson et al., 1992b).

	2020		2050		2100	
	[mill. m^3]	[PJ]	[mill. m^3]	[PJ]	[mill. m^3]	[PJ]
European Russia	280.9	1966	290.1	2031	290.6	2034
Independent states						
Ukraine	12.1	85	12.6	88	12.6	88
Moldavia	0.4	3	0.4	3	0.4	3
Belarus	11.5	81	11.6	81	11.6	81
Baldic States	10.3	72	10.4	73	10.4	73
Total Former European USSR	315.2	2207	325.1	2276	325.6	2279

2.4.3. THE BIOENERGY POTENTIAL OF RUSSIA

In general there is little information available on bioenergy consumption in Russia and does not picture the importance woodfuel has in rural areas and in the forest industry.

For 1991, FAO (1995) suggests that 81 million m^3 of fuelwood and charcoal were burned for energy purposes. A significant decrease since 1991 can be seen from the 1993 figure from Nilsson (1996). He suggests an increase in fuelwood production by 63 % during 1993-2020, from 49 million m^3 to 80 million m^3.

According to Shvidenko et al. (1995), the fuelwood harvested and used by the forest industry was some 60 million m^3 in 1989. The fraction of wood wastes burned for energy is 13-18 million m^3 but is likely to be significantly underestimated. Additionally residential consumption is estimated to 75 million m^3 in 1990 which adds up to 153 million m^3 of consumed wood for energy purposes. In this context it may be of interest to mention that the forest biomass that is destroyed by forest fires amounted to more than 250 million m^3 in 1990.

Table 2.4.6. Wood-energy use and according roundwood equivalents in Russia.

	Reference year[1]		2020	
	[million m^3]	[PJ]	[million m^3]	[PJ]
Wood-energy use				
FAO (1995)[2]	81.1	568	-	-
Nilsson (1996)[2]	49.0	343	80.0	560
Shvidenko et al. (1995)	153.0	1071	-	-

[1] The reference years for FAO (1995), Nilsson (1996) and Shvidenko et al. (1995) are 1991, 1993 and 1989/90 respectively.
[2] Numbers refer most probably only to commercial use only and does not include by-products.

2.5. RESOURCES AND POTENTIALS OF CHINA

China's forests are large in absolute size (128.5 million ha of forested area), but very limited given the size of the country (960.3 million ha) and with a population of over 1.2 billion. The growing stock is estimated to 10.1 billion m^3. Waggener et al. (1996) describe trends and recent developments of the China's forest sector and indicate that these forests have been heavily utilized in the past without appropriate reforestation and protection. That is why the productivity and the area of forests have declined. Although some 27 % of China's forested area are claimed to be plantations carried out during the last 40 years, the annual rate of new plantations is rather low, about 1% of the forested area during 1989-93.

There are no indications of major changes of the current situation. But it remains uncertain whether China's forest resource will coop with potential land-use changes and increasing demands for natural resource, which are pushed forward by the prospering economy. This concern is supported by the fact that the roundwood production has increased by 40 % between 1976 and 1992 as shown in Table 2.5.1., while the area for forests and woodlands decreased by 10 % during the same period (FAO, 1993).

Table 2.5.1. Development of China's forest resource (Waggener et al., 1996).

	Industrial roundwood		Fuelwood		Total		Forests & woodlands	
	[mill. m^3]	[PJ]	[mill. m^3]	[PJ]	[mill. m^3]	[PJ]	[mill. ha]	[%]
1976	67.610	473	142.800	1000	210.410	1473	140.024	-
1992	90.931	637	203.701	1426	294.632	2062	126.515[1]	-10

[1] Refers to 1991.

There is limited information available on the future development of China's forest resources. In Nilsson (1996) it is suggested that the production of industrial roundwood will remain quite stable at 100 million m^3 while the production of fuelwood and charcoal will increase by 20 % to 240 million m^3 by year 2020. An older near to middle term outlook for demand of forest products, (Waggener et al., 1996) indicates a strong increase in wood consumption between 2000 and 2040 which are primarily based on per capita consumption rates that can be regarded as "high" forecasts. Even low per capita consumption forecasts provide an awareness of the magnitude of impacts both on domestic markets as well as on international trade of forest products by the future Chinese demand.

Table 2.5.2. Projections for China's wood consumption and production.

	Industrial roundwood [mill. m^3]	[PJ]	Fuelwood [mill. m^3]	[PJ]	Total roundwood [mill. m^3]	[PJ]
FAO (1995)						
1993	100.6	704	200.1	1401	300.7	2105
Waggener et al. (1996)						
Low	291	2037	-	-	-	-
2025 Medium	546	3822	-	-	-	-
High	910	6370	-	-	-	-
Low	388	2716	-	-	-	-
2040 Medium	775	5425	-	-	-	-
High	1163	8141	-	-	-	-
Nilsson (1996)						
Total	85-100	595-700	240	1680	325-340	2275-
2020 Coniferous	53-60	371-420	-	-	-	2380
Deciduous	32-40	224-280	-	-	-	-
						-

3. CONCLUSION

In the following the earlier discussed detailed assessments are summarized.

3.1 . WEST AND EASTERN EUROPE

A summary of the country level assessment on national resources and potentials for forest biomass energy is displayed in Table 3.1.

Table 3.1. Results of the country level assessment of biomass energy use and its potentials in Europe.

Country	Population	Primary energy consumption	Energy consumption per capita	Wood-based energy consumption	Wood-based energy consumption[1]	Share fuelwood at roundwood production	Potential wood-energy use	Potential wood-energy use	Potential wood-energy use	Potential wood-energy use
Reference year	1992	1992	1992	low-high	low-high	1992	low	low	high	high
Unit	[million inh.]	[PJ]	[GJ/inh.]	[PJ]	[%]	[%]	[PJ]	[%]	[PJ]	[%]
Source	EC (1994a)	EC (1994a)	-	This study	This study	FAO (1994)				
Finland	5.1	1222.5	239.7	155.8-188.4	12.7-15.4	7.5	263.8	21.6	360.0	29.4
Norway	4.3	891.8	207.4	15.7-58.7	1.7-6.5	9.2	63.7	7.1	108.0	12.1
Sweden	8.7	1955.2	224.7	216.0-226.1	11.0-11.6	6.8	221.5	11.3	436.0	22.3
NORDIC	**18.1**	**4069.5**	**224.8**	**387.5-473.2**	**9.5-11.6**	**7.3**	**549.0**	**13.5**	**904.0**	**22.2**
Austria	7.9	1138.8	144.2	72.2-132.9	6.4-13.0	23.3	68.1	6.0	120.0	10.5
Switzerland	6.9	1059.3	153.5	9.2-13.3	0.9-1.3	18.6	17.7	1.7	37.0	3.5
CENTRAL	**14.8**	**2198.1**	**148.5**	**81.4-146.2**	**3.7-6.7**	**22.1**	**85.8**	**3.9**	**157.0**	**7.1**
Belgium + Luxemb.	10.4	2274.6	218.7	12.5-14.4[2]	0.6-0.7[2]	13.0	21.0	1.0	21.0	1.0
Denmark	5.2	753.6	144.9	11.4-31.8	1.6-4.1	22.0	17.0	2.3	21.0	2.8
France	57.4	9285.5	161.8	368.0-407.0	4.2-4.4	24.5	347.0	3.7	384.0	4.1
Germany	80.1	13979.7	174.5	49.8-96.9	0.3-0.7	10.6	110.5	0.8	293.0	2.1
Ireland	3.6	417.4	115.9	4.4	1.0	2.6	8.0	1.9	8.0	1.9
Italy	57.9	6499.6	112.3	115.0-152.0	1.8-2.4	53.3	180.0	2.8	180.0	2.8
Netherlands	15.2	2880.5	189.5	15.0-24.2	0.2-0.8	10.1	25.8	0.9	90.6	3.1
U.K.	57.7	8967.3	155.4	9.9-14.8	0.1-0.2	4.3	34.2	0.4	42.0	0.5
EEC-9	**287.5**	**45058.2**	**157.3**	**587.9-745.5**	**1.3-1.6**	**20.0**	**743.5**	**1.7**	**1039.6**	**2.3**
Albania	3.3	62.8	19.0	16.3	26.0	60.9	20.9	33.3	23.6	37.6
Greece	10.3	924.0	89.7	58.5	6.5	58.9	25.0	2.7	30.0	3.2
Portugal	9.8	698.8	71.3	91.3	14.1	5.1	71.2	10.2	124.0	17.7
Spain	39.1	3843.9	98.3	156.1	4.1	12.5	100.0	2.6	133.0	3.5
Turkey	58.8	2324.9	39.5	95-116	4.1-5.0	63.5	247.0	10.6	258.0	11.1
Former Yugoslavia	23.8	1385.8	58.2	33.3	2.4	28.5[3]	42.3	3.1	47.6	3.4
SOUTHERN	**145.1**	**9240.2**	**63.7**	**450.5-471.5**	**4.9-5.1**	**37.2**	**506.4**	**5.4**	**616.2**	**6.7**
EU	**368.4**	**54841.4**	**148.9**	**1328.2-1631.1**	**2.4-3.0**	**19.2**	**1526.4**	**2.8**	**2275.9**	**4.1**
Bulgaria	9.0	770.4	85.6	19.8	2.6	53.0	19.8	2.6	21.0	2.8
For. Czechoslovakia	15.5	2373.9	153.2	13.4	0.6	10.2	13.4	0.6	14.2	0.6
Estonia	1.5	251.2	163.1	8.5	3.5	37.6	15.0	3.5	15.0	3.7
Hungary	10.3	1084.4	105.3	23.3	1.8	43.9	23.3	1.8	24.6	1.9
Latvia	2.7	334.9	125.6	7.4	2.2	28.3	13.0	2.2	13.0	2.3
Lithuania	3.6	460.5	127.9	10.5[4]	2.3	30.6[5]	18.5	2.6	18.5	2.8
Poland	38.4	3981.6	103.7	33.8	0.8	17.0	33.8	0.8	35.7	0.8
Romania	22.8	1921.7	84.3	28.3	1.4	20.5	28.3	1.4	29.9	1.5
EASTERN	**103.8**	**11178.6**	**107.7**	**145.0**	1.2	30.1	**165.1**	1.5	**171.9**	1.5
TOTAL	**569.3**	**71744.6**	**126.0**	**1652.3-1981.4**	**2.3-2.8**	**18.5**	**2049.8**	**2.9**	**2888.7**	4.0

[1] Refers to reference year of wood derived energy consumption.
[2] Luxembourg included in Belgium.
[3] Figure refers to year 1990.

As explained previously, stemwood which is ascribed to annual fellings and growing stock of European forest resources is converted to biomass. Table 3.2. presents total aboveground biomass potentials from annual fellings, growing stock and biomass used for energy production.

Table 3.2. Overview of biomass potentials for Europe (regular font in million m^3; *italic* font in PJ).

	2020		2050		2100	
[mill. m^3] *[PJ]*	stemwood	biomass[1]	stemwood	biomass[1]	stemwood	biomass[1]
GROWING STOCK						
Pajuoja (1995)	25421.2	33047.6	31464.1	40903.3	-	-
	177948	*231333*	*220249*	*286323*	-	-
Nilsson et al. (1992a)[2]	20575.0	26747.5	22471.4	29212.8	25632.2	33321.9
	144025	*187233*	*157300*	*204490*	*179425*	*233253*
FELLINGS						
Pajuoja (1995)	497.4	646.6	525.0	682.5	-	-
	3482	*4526*	*3675*	*4778*	-	-
Nilsson et al. (1992a)[2]	563.8	732.9	591.3	768.7	620.4	806.5
	3947	*5130*	*4139*	*5381*	*4343*	*5646*
Nilsson (1996)	413-491	537-638	-	-	-	-
	2891-3437	*3759-4466*	-	-	-	-
Net annual increment						
Pajuoja (1995)	696.2	905.1	741.3	963.7	-	-
	4873	*6336*	*5189*	*6746*	-	-
Unused resource[5]	132-244	172-318	150-216	195-281	-	-
	924-1708	*1204-2226*	*1050-1512*	*1365-1967*	-	-
WOOD-ENERGY USE						
CEC (1991)	-	101.7[3]	-	-	-	-
	-	*712*	-	-	-	-
UN (1996)	-	265-325	-	-	-	-
	-	*1855-2268*	-	-	-	-
This study	-	293-413[4]	-	-	-	-
	-	*2050-2889*	-	-	-	-

[1] A rather conservative conversion factor of 1.3 is assumed for the ratio *Total Biomass/Stemwood*.
[2] Refers to the land expansion scenario.
[3] Refers to a time horizon of 2010.
[4] Refers to biomass that is expected to be available for energy production.
[5] Difference between fellings and net annual increment.

3.2. RUSSIA

As explained previously, stemwood which is ascribed to annual fellings and growing stocks of Russian forest resources is converted to biomass. Table 3.2. presents total aboveground biomass potentials from annual fellings, growing stock and biomass used for energy production.

Table 3.3. Overview of biomass potentials for Russia (regular font in million m^3; *italic* font in PJ).

	2020		2050		2100	
[mill. m^3] *[PJ]*	stemwood	biomass[1]	stemwood	biomass[1]	stemwood	biomass[1]
GROWING STOCK						
Nilsson et al. (1992b)[2]						
European Russia	20834	27084	20004	26006	18625	24213
	145838	*189588*	*140031*	*182040*	*130375*	*169488*
Former Europ. USSR	22931	29810	22197	28856	20976	27269
	160517	*208672*	*155379*	*201993*	*146832*	*190882*
FELLINGS						
Backman (1994)						
European Russia	246	320	-	-	-	-
	1722	*2239*	-	-	-	-
Asian Russia	371	482	-	-	-	-
	2597	*3376*	-	-	-	-
Nilsson et al. (1994)						
European Russia	196	255	-	-	-	-
	1369	*1784*	-	-	-	-
Asian Russia	329	428	-	-	-	-
	2306	*2994*	-	-	-	-
Nilsson (1996)						
Total Russia	285-395	371-514	-	-	-	-
	1995-2765	*2594-3595*	-	-	-	-
WOOD-ENERGY USE						
Nilsson (1996)	155[3]	202	-	-	-	-
	1085[3]	*1411*	-	-	-	-

[1] A rather conservative conversion factor of 1.3 is assumed for the ratio *Total Biomass/Stemwood.*

[2] The information given for Russia in Table 2.4.3. is adjusted because it considers only commercial forests, which corresponds to 68 % of the total forested areas.

[3] As has been shown by Shvidenko et al. (1995) residential fuelwood consumption is obviously not included in official statistics. In contrast to industrial consumption of fuelwood, residential consumption can be expected not to be so much effected by economic decline and therefore is added to Nilsson's original figure.

3.4. SUMMARIZED OVERVIEW

The availability of forest biomass for Europe, Russia and China based on current knowledge is presented in Table 3.4. The information on growing stock indicate the size of the total resource or how much biomass is theoretical available but does not clarify if and when biomass will become available. Information on felling and increment rates reflects the technologically availability of forest biomass on an annual basis and the harvesting levels are somehow comparable to the biomass *potentials* used by IIASA's ECS-Project[2]. The latter will allow us to draw conclusions on how the potential quantity of biomass for energy usage may develop. The information on wood energy refers more closely to the biomass *consumption* figures of the same project. The wood energy figures are derived from growing stock, harvesting activities, and pattern of biomass utilization.

Table 3.4. Availability of forest biomass in Europe, Russia and China.

	Current [PJ]	2020 [PJ]	2050 [PJ]	2100 [PJ]
WESTERN EUROPE				
Growing stock	88719-103712	110265-133666	125745-165870	141137
NAI[2]	3459	3928	4216	-
Fellings	2489-2498	2791-3037	2951-3225	3362
Wood energy[1]	1458-1787	1822-3132	-	-
EASTERN EUROPE[3]				
Growing stock[4]	36063-37132	41607-44282	43971-50533	48064
NAI[2]	949	946	973	-
Fellings	587-814	691-910	724-913	900
Wood energy	195	228-243	-	-
RUSSIA				
Growing stock	867314-931770	-	-	-
	233310[5]	189588[6]	182040[6]	169488[6]
Fellings	2240/1219[7]	3815-4319	-	-
Wood energy	1071	560-1082[8]	-	-
CHINA				
Growing stock	70957	-	-	-
Fellings	2062	2275-2380	-	-
Wood energy	1426	1680	-	-

[1] Turkey included in Western Europe.
[2] NAI = Net annual increment.
[3] Includes the Baltic states, Albania and Former Yugoslavia.
[4] The forest land area of 8.2 mill. ha of the Baltic states and Albania has been added to the information from Nilsson et al. (1992a).
[5] European Russia only; derived from the Russian Federal Forest Service (1995).
[6] European Russia only; derived from Nilsson et al. (1992b).
[7] Refers to 1988 and 1993 harvesting levels.
[8] Nilssons (1996) figures updated by residential fuelwood consumption from Shvidenko et al. (1995).

[2] The consumption and potential of biomass use for energy for 11 world regions has been assessed and employed for modelling purposes by the Environmentally Compatible Energy Strategies Project at the International Institute for Applied Systems Analysis (IIASA).

Figures displayed in Table 3.4. indicate that the current trend of a slowly increasing forest land area, underutilization of the forest resources, and increased growing stock in European forest will continue in the future due to economic, social and political considerations. The underutilization of the forest resources is remarkable due to the fact that fellings are estimated to have increased by a magnitude of 20 % and 35 % in year 2050 and 2100 respectively. Wood energy production is estimated to increase by 25-75 % from current levels to year 2020.

For the Russian forest resource the main limitation is that a major share of forests are actually not exploitable. While natural hazards such as forest fires threaten the resource overexploitation takes place in populated areas and in areas with established transportation infrastructure in the southern part of Siberia and Far East.

Recent developments of China's forest sector indicate that these forests have been heavily overutilized in the past without appropriate reforestation and protection. There has been a decline of forest area and forest productivity, which contrast an increased harvest during the same period. There are no indications of major changes of this current situation, particularly under the potential land-use changes due to the prospering economy. The wood energy consumption is estimated to increase by 18 % by year 2020.

When comparing the total biomass consumption and total biomass potentials for Europe, Russia and China employed by IIASA's ECS-Project (Table 3.5.) with the estimates for forest biomass in Table 3.4. the regional differences become obvious.

Table 3.5. Biomass consumption and biomass potentials used by IIASA's ECS-Project.

[PJ]	Western Europe ECS	Western Europe Difference[1]	Eastern Europe ECS	Eastern Europe Difference[1]	Former Soviet Union ECS	Former Soviet Union Difference[1]	China ECS	China Difference[1]
1990								
Consumption	1577	-119-210	63	132	189	882	378	1048
Potential	1892	597-606	331	256-483	1470	260[1]	8833	-6771
2020								
Consumption	3588	-70-1240	332	-104--89	956	-396-126	3769	-2089
Potential	5711	-2920- -2674	1113	-422--203	11221	-7406- -6902	10092	-7817- -8841
2050								
Consumption	4461	-	939	-	2699	-	6607	-
Potential	7597	-4646- -4372	2781	-2057- -1868	27055	-	13403	-
2100								
Consumption	4658	-	1373	-	3950	-	6865	-
Potential	12217	-8855	4982	-4082	31175	-	17503	-

[1]Difference between consumption and potential in Table 3.5. and wood energy and fellings in Table 3.4. respectively.
[12]Compared with mean value of 1988 and 1993 felling rate.

It can be seen that the current (1990) biomass *consumption* for Eastern Europe, Russia and China is substantially underestimated by IIASA's ECS-Project. In China the dominant biomass resource is to be found outside the forest resources.

The question arises whether enhanced efforts to produce forest biomass can fill up the gaps between potentially available forest biomass and the foreseen total biomass for energy production as indicated in Table 3.5. The option of growing forests for wood energy production can be highlighted by a forest plantation program for carbon sequestration by Nilsson and Schopfhauser (1995). The land area which is both suitable and available for a feasible forest planatation program indicates some 8 million ha in Europe, more than 66 million ha in the Former Soviet Union and 62 million ha in China. With a starting point in 2000 and a program period of 100 years, by year 2050 and 2100 forest plantations could provide additional wood-energy of 3020 PJ and 2130 PJ respectively of which nearly one half could be produced in Russia. This indicates that enhanced forest biomass production is unlikely to provide enough bioenergy to satisfy ECS's biomass potentials.

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